BENTHIC FORAMINIFERAL TAXONOMY, DISTRIBUTION AND ECOLOGY IN THE ARABIAN GULF

BY

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To Mike, for everything…

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ABSTRACT

Full Name : Abduljamiu Olalekan Amao

Thesis Title : BENTHIC FORAMINIFERAL TAXONOMY, DISTRIBUTION AND ECOLOGY IN THE ARABIAN GULF

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This research was designed to carry out qualitative and quantitative analysis of benthic foraminifera assemblages from shallow intertidal to deep offshore environments of the Saudi Arabian parts of the Arabian Gulf. Benthic foraminifera are among the major carbonate producers in modern Arabian Gulf waters and are found living in all marine habitats. Their fossil remains comprise a major proportion of petroleum-bearing carbonate rock in Eastern Saudi Arabia. Their distribution in marine sediments reflects environmental gradients such as water depth, substrate parameters, the availability of food, and in many modern settings they are affected by anthropogenic pollution. The main objective of the study was to understand environmental parameters that affect the distribution of benthic foraminifera. The research was aimed at conducting a survey of benthic foraminifera in the Saudi Arabian sector of the Arabian Gulf, make an inventory of species and document the distribution of foraminiferal biofacies and dead assemblages with respect to water depth and substrate parameters. Subsequently, several relevant topics were investigated and are presented in the following subheadings.

EPIBIONT (PARASITIC PAPER)

This study focused on the possible ‘parasitism-like’ relationship between the epibiont *Cymbaloporetta* sp. and basibiont benthic foraminifera including *Agglutinella soriformis*, *Adelosina carinatastriata*, *Pseudotriloculina* sp. and *Spiroloculina indica* from a sample collected off the east coast of Bahrain in the Arabian Gulf. There are no indications of preferential host selection, the epibiont seems to attach onto any available basibiont. However, constriction of the test and subsequent growth of the basibiont’s chambers at the point of attachment of the epibiont might suggest an early link in their ontogeny. This biotic relationship has implications on the basibionts’ development and ontogeny that eventually results in the development of foraminiferal abnormalities. The finding of morphological test abnormalities caused by an epibiont in an unpolluted environment has important implications for the use of the abnormalities for pollution biomonitoring.

PSEUDONUBECULINA

This study describes an enigmatic new agglutinated benthic foraminiferal genus and species that shares some morphological features with the *Reophax*, *Hormosina* and *Nubeculina* groups. *Pseudonubeculina arabica* n. gen. n. sp. is characterized by its

uniserial chamber arrangement, coarsely agglutinated bilamellar test wall with white high -Mg calcite cement, and a terminal slit-like aperture formed by the flat sides of two or more large agglutinated grains. The new genus cannot be placed within any of the previously described families of the Miliolida. The current classification of the Miliolida does not accommodate a genus with a wholly uniserial chamber arrangement. This species can easily be distinguished by its prominent terminal slit-like aperture, formed using the flat sides of two or more large agglutinated grains, lined by an imperforate rim of secreted calcite. The species has a restricted area and depth distribution in the Arabian Gulf.

PSEUDOTRILOCULINA

This study describes a new species of benthic foraminifera belonging to the miliolid foraminiferal genus *Pseudotriloculina*. The species *Pseudotriloculina hottingeri* n. sp. is here described from several locations sampled in the Arabian Gulf. The species is distinguished by its U-shaped chambers, arranged initially in an indistinct triloculine and later in a pseudotriloculine manner, and its porcelaneous wall with longitudinal or bifurcating costae ornamentation running along the chambers from the posterior end to the apertural margin. It also has a short, broad, spoon-like bifid tooth within a terminal aperture and a broad collar draped on the last chamber. The species is named after Professor Lukas Hottinger who first described the species from the Gulf of Aqaba, Red Sea. The species has a restricted bathymetric and ecological distribution in the Arabian Gulf. The species has a depth range 0.02–17 m, tolerates salinity of 36–52 ppt and a temperature of 27–30°C. Specimens were found in 20 samples out of 78 sampling stations studied in the entire Arabian Gulf. The species appears to have ecological significance in understanding epibiont-basibiont interactions and can also be used to delineate restricted environments based on its ecological preferences.

SALWA

This study documents the foraminiferal diversity, abundance and deformity rates in the hypersaline Salwa Bay, near the Saudi Arabia–Qatar Border. The benthic foraminiferal species were dominated by porcelaneous taxa (85.1%), followed by hyaline (14.9%). The ten most abundant species are: *Peneroplis pertusus* (24.0%), *P. planatus* (15.4%), *Coscinospira hemprichii* (9.1%), *Ammonia convexa* (6.6%), *Quinqueloculina* sp. 1 (3.9%), *Elphidium advenum* (3.9%), *E. craticulatum* (3.5%), *E. gerthi* (3.0%), *A. tepida* (3.0%), *Elphidium* sp. 1 (3.0%). *Peneroplis pertusus*, *P. planatus* and *C. hemprichii* account for about 48% of the assemblage. A quarter of the processed samples consist of living (Rose Bengal stained) individuals, and approximately 43% of the most common taxa, i.e., *Peneroplis*, *Coscinospira*, *Miliolinella*, *Ammonia*, *Elphidium*, *Triloculina*, *Quinqueloculina* and *Lachlanella,* exhibit mild to severe deformities such as fusion of two adults or double tests, protuberances on the spiral side, abnormal chambers arrangement, abnormal shape of the proloculus, and modification of the coiling plane in several chambers. *Peneroplis* (58.4%) and *Coscinospira* (17.1%) account for 75.5% of all the observed test deformities. I speculate that the combination of high summer temperatures and salinities, and the ecology of the taxa encountered, are responsible for the high rates of deformities, high abundances, and comparatively low diversity in Salwa Bay.

BAHRAIN

This study documents the foraminiferal diversity across a semi-enclosed pool in eastern Bahrain that we named "Murray's Pool" because this is the same location as the one studied by Basson and Murray (1995), the only previous study of foraminifera in this sector of the Arabian Gulf. The area was subdivided into six subenvironments based on distinguishable physical environmental features, namely tidal channel, tidal flat, *Salicornia* marsh, algal mat, sheltered inner lagoon, and back marsh pool. Faunal analysis from these six shallow-water subenvironments reveals two main assemblages of benthic foraminifera: an *Ammonia convexa-Elphidium advenum-Peneroplis pertusus* assemblage and an *Ammonia convexa-Coscinospira hemprichii-Peneroplis pertusus* assemblage. The most abundant species across all the subenvironments are *P. pertusus*, *A. convexa*, *C. hemprichii*, and *E. advenum*. Species assemblage composition and percentage abundances were determined for each subenvironment; the tidal flat subenvironment shows the highest total abundance, but has 24 fewer species compared to the sheltered inner lagoon. I also noted the proportions of living foraminifera and juveniles in all the subenvironments to understand the distribution of biofacies within the lagoon. The numbers of juvenile miliolid foraminifera are highest in the tidal channel and the two subenvironments adjacent to the tidal channel.

IRANIAN COAST

This study focuses on the distribution of benthic foraminifera along the Iranian coast of the Gulf from the northeast close to Shatt Al-Arab/Arvand Rud to the southeast near the Strait of Hormuz where it connects to the Indian Ocean. The Gulf is a naturally stressed environment due to extremes of salinity, temperatures and anthropogenic influences such as rapid urbanization projects, maritime transport, large numbers of desalination plants and oil platforms. These activities overtime continue to compound the already stressed environment. Historical records on foraminiferal diversity and distribution in the Gulf commonly underestimate its benthic foraminiferal composition and diversity. Thirty-two samples collected from depths ranging between 20 to 45 m were analyzed for total foraminiferal assemblages. A total of 224 benthic foraminiferal species and subspecies belonging to 63 genera, 34 families, 22 superfamilies and 6 orders were recognized. The assemblages are dominated by hyaline taxa (45.3%) and porcelaneous foraminiferal (35.3%), while agglutinated foraminiferal groups comprise a lower proportion (19.4%). The ten most abundant genera include *Asterorotalia* (13.3%), *Quinqueloculina* (12.4%), *Bolivina* (9.8%), *Nonion* (8.6%), *Ammonia* (5.5%), *Textularia* (5.4%), *Elphidium* (5.2%), *Cibicides* (3.9%), *Challengerella* (3.6%) and *Hanzawaia* (3.4%). The most common species are *Nonion* sp. 1 (5.5%), *Asterorotalia dentata* (5.0%), *Quinqueloculina* sp. 1 (4.8%), *Nonion* sp. 2 (4.5%), *Rotalinoides* cf. *R. gaimardii* (3.3%), *Asterorotalia* sp. 3 (3.2%), *Quinqueloculina* sp. 8 (3.1%), *Bolivina* cf. *B. persiensis* (3.0%), *Bolivina* cf. *B. striatula* (2.9%), and *Ammonia* sp. 1 (2.9%). I speculate that feeding strategy, e.g., herbivore (*Nonion, Ammonia, Elphidium and Asterorotalia*), increase of finer sediments (mud), availability of nutrients and presence of oxygen are factors controlling the diversity and distribution of benthic foraminifera in the Gulf. Due to the importance of this water body in a changing world climate, this study updates the knowledge on the type and distribution of benthic foraminiferal groups.

ملخص الرسالة

الإسم: عبد الجامع اولوكان أماو

عنوان الأطروحة: تصنيف, توزيع وبيئة المنخربات القاعية في الخليج العربي

التخصص: الجيولوجيا

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لقد تم تصميم هذا البحث بغرض إجراء تحليل نوعي وكمي لمجموعات المنخربات القاعية من البيئات المدية الضحلة إلى البيئات البحرية العميقة في جزء من الخليج العربي للمملكة العربية السعودية. المنخربات القاعية تعتبر من بين المنتجين الرئيسين للكربونات في مياه الخليج العربي الحديث وقد وجدت تعيش في جميع البيئات او الأوساط البحرية. وتشكل بقاياها نسبة كبيرة من الصخور الخازنة للنفط في الجزء الشرقي من المملكة العربية السعودية. توزيع المنخربات القاعية في الرواسب البحرية يعكس التدرجات البيئية مثل عمق المياه, معاملات طبقات المياه، وتوافر الغذاء، وفي العديد من الانظمة الحديثة تتأثر بالملوثات البشرية. إن الهدف الرئيسي من هذه الدراسة هو فهم العوامل البيئية التي تؤثر على توزيع المنخربات القاعية. وقد هدف البحث إلى إجراء دراسة استقصائية للمنخربات القاعية في القطاع السعودي من الخليج العربي وجرد المخزون من الأنواع وتوثيق توزيع سحنات المنخربات والتجمعات الميتة فيما يتعلق بعمق المياه ومعاملات طبقات المياه. وبالتالي، قد تم التحقيق من العديد من الموضوعات ذات الصلة والتي يتم عرضها في العناوين الفرعية التالية.

EPIBIONT (ورقة الطفيلية)

ركزت هذه الدراسة علي العلاقة الطفيلية بين نوع epibiont Cymbaloporetta و basibiont من المنخربات القاعية والتي تشمل *Agglutinella soriformis*, *Adelosina carinatastriata*, نوع *Pseudotriloculina* و *Spiroloculina indica* والتي تم الحصول عليها من عينات جمعت الشاحل الشرقي للبحرين علي الخليج العربي. لاتوجد مؤشرات علي اختيار انتقائي , فيما يبدو أن epibiont تتعلق علي اي basibiont متاحة. ومع ذلك التقلصات علي الصدفة و النمو اللاحق في حجرات basibiont في نقطة الالتصاق لل epibiont ربما تقترح وجود رابط مبكر في تطور الجنين بينهم. هذه العلاقة الحيوية لها آثار علي تطور basibionts وتطور الجنين والذي يؤدي في نهاية المطاف الي نمو غير عادي في المنخرباتز هذا الاكتشاف في الاختلافات الغير عادية تسببت فيها epibiont في البيئات الغير ملوثة والتي لها مدلولات في استخدام هذا الشذوذ في الرصد الحيوي للتلوث.

PSEUDONUBECULINA

تصف هذه الدراسة جنس وانواع جديدة غامضة من المنخرات القاعية الملتصقة و التي تتشارك بعض المظاهر مع مجموعات *Hormosina ,Reophax, Hormosina* و *Reophax*.جنس ونوع ال *Pseudonubeculina arabica* يتميزبحجرات ذات ترتيب uniserial, الملتصقات الخشنة ذات الصدفة التي لها جدار من نوع bilamellar مع كالسيت ابيض بمحتوي ماغنزيوم عالي, وفتحة ذات شق نهائية والتي تكونت من حبتين او اكثر ذات سطح مسطح وحجم كبير. هذا الجنس الجديد لايمكن وضعه مع اي من العوائل التي سبق وصفا للميلويليد. التصنيف الحالي للميلويليد لايستوعب جنس مع ترتيب غرفة uniserial بالكامل. هذا النوع بسهوبة يمكن التعرف عليه من خلال فتحة طرفية بارزة, والتي تشكلت عن طريق جانب مسطح لجبتين او اكثرملتصقة كبيرة الحجم, والتي تحفها حافة مثقبة من الكالسيت. هذه النواع لها نطاق وعمق ضيق او محصور في منطقة الخليج العربي.

PSEUDOTRILOCULINA

تصف هذه الدراسة انواع جديدة للمنخربات القاعية والتي تنتمي لمنخربات الملويليد من جنس *Pseudotriloculina* . نوع *Pseudotriloculina hottingeri* n. sp هنا وصف لعينات اخذت من عدة مواقع من الخليج العربي. هذا النوع يتميز بغرف علي شكل حرف U, مرتبة في البداية في شكل triloculine غير واضحة وفي مرة اخري في اسلوب pseudotriloculine, و لها جدار porcelaneous مع اضلاع طولية او bifurcating والتي تشغل علي نهايات علي طول الغرف من نهاياتها الخلفية الي أطرافها. كما ان لديها اسنان واسعة ذات شكل ملعقي في الفتحة النهائية وطوق ملفوف في الفتحة النهائية. وصف هذا النوع لاول مرة بعد البروفيسير لوكاس هوتينغر في خليج العقبة ,البحر الاحمر. هذه الانواع مقيدة العمق والتوزيع البيئي في الخليج العربي. هذه الانواع لها عمق يتراوح من 0.02 الي 17 متر, تتوائم مع ملوحة 36 الي 52 جزء في الالف ودرجة حرارة تتراوح من 30 الي 27 درجة مئوية. تم العثور علي هذه الانواع في 20 عينة من اصل 78 عينات من المحطات المخصصة لجمع العينات من كل الخليج العربي. يبدو ان لهذه الانواع اهمية بيئية في فهم تفاعلات ال epibiont-basibiont والتي يمكن ان تستخدم لتحديد البيئات المقيدة إعتمادا علي التفضيلات البيئية.

سلوى

توثق هذه الدراسة تنوع المنخربات, وفرتها ومعدلات التشوه في البيئة شديدة الملوحة في خليج سلوى, بالقرب من الحدود بين المملكة العربية السعودية وقطر. انواع المنخربات القاعية تسودها انوع porcelaneous taxa (85.1%), تليها hyaline (14.9%) . اكثر 10 انواع سائدة هي : *Peneroplis pertusus* (24.0%), P. planatus (15.4%), *Coscinospira hemprichii* (9.1%), *Ammonia convexa* (6.6%), Quinqueloculina sp. 1 (3.9%), *Elphidium advenum* (3.9%), *E. craticulatum* (3.5%), *E. gerthi* (3.0%), *A.tepida* (3.0%), *Elphidium sp. 1* (3.0%), *Peneroplis pertusus, P. planatus* و *C. hemprichii* حسبت بنسبة حوالي 48 % من الانواع. ربع العينات المحللة تتألف من أفراد حية (صبغت بالروز بنغال), وهي حوالي 43% من الانواع الاكثر شيوعا" مثل *Peneroplis, Coscinospira, Miliolinella, Ammonia, Elphidium, Triloculina, Quinqueloculina* و *Lachlanella*, تظهر تشوهات خفيفة الي حادة مثل التحام صدفتين بالغتين او صدفة مزدوجة, نتوءات علي الجانب الملتف, وترتيب غرف غير طبيعية, وشكل غير طبيعي لل proloculus, و تحورات في محور اللف في عديد من الغرف. Peneroplis (58.4%) و Coscinospira (17.1%) والتي حسبت بنسبة 75% لكل الاصداف المشوهة الملاحظة. أنا أفترض أن الجمع بين درجات الحرارة في الصيف و الملوحة العاليتين, وبيئة الأصناف المتعرف عليها, هي المسؤولة عن معدلات التشوه العالية, الوفرة العالية, وتنوع منخفض نسبيا" في خليج سلوى.

البحرين

توثق هذه الدراسة تنوع المنخربات عبر تجمع شبه مغلق في شرق البحرين والذي سميناها " حوض مولي" لأنه هو نفس الموقع الذي تمت دراسته من قبل باسون وموراي في العام 1995, وتعتبر الدراسة الوحيدة التي تمت في السابق في هذا الجزء من الخليج العربي. تم تقسيم المنطقة الي ستة بيئات فرعية على أساس الخصائص الفيزيائية البيئية المميزة, وهي قناة المد, مسطح المد, مستنقع ال Salicorni, بساط الطحالب, المناطق المحمية من البحيرة, وخلف حوض المستنقع. تحليل الحيوانات من هذه الست بيئات الضحلة كشف عن وجود تجمعين رئيسيين للمنخربات القاعية: تجمع ال *Ammonia convexa-Elphidium advenum-Peneroplis pertusus* و تجمع ال *Ammonia convexa-Coscinospira hemprichii-Peneroplis pertusus*. الانواع الأكثر وفرة ضمن الست بيئات هي *P. pertusus*, *A. convexa*, *C. hemprichii* و *E. advenum*. تكوين تجمع هذه الانواع و نسبة وفرتها تم تحديدها لكل بيئة فرعية; بيئة مسطح المد والتي تظهر مجموع وفرة عالي جدا"و ولكن لها عدد 24 نوع أقل مقارنة بالمناطق المحمية من البحيرة. لقد لاحظت أيضا" ان نسبة المنخربات الحية والأحداث في كل البيئات الفرعية من أجل فهم توزيع السحنات الحيوية في البحيرة. عدد الأحداث من منخربات الميلويلد هي الاعلي في قناة المد والجزر والبيئات الفرعية المجاورة لقناة المد والجزر.

الساحل او الشاطئ الإيراني

تركز هذه الدراسة على توزيع المنخربات القاعية علي طول الشاطئ الإيراني علي الخليج من الشمال الشرقي بالقرب من شط العرب/ ارياند رود الي الجنوب الشرقي قرب مضيق هرمز حيث يتصل بالمحيط الهندي. الخليج هو بيئة قاسية بسبب علو درجات الملوحة, الحرارة و التأثيرات البشرية مثل مشاريع التمدن, النقل البحري, العدد الضخم من محطات تحلية المياه و منصات النفط هذه النشاطات مع مرور الوقت تستمر وتيف عبء إضافي بالفعل للبيئة القاسية. السجلات التاريخية عن تنوع المنخربات وتوزيعها في الخليج في العادة تقلل من تكوينها من المنخربات القاعية و تنوعها. عدد 32 عينة تم تحليلها من أعماق تتراوح بين 20 و 45 متر لمجموع تجمعات المنخربات. تم التعرف علي ما مجموعه 224 نوع و نوع فرعي والتي تنتمي الي 63 جنس, 34 سلالات, 22 فوق سلالات و 6 رتب. وهي الانواع الزجاجية (45.3%) و المنخربات الخزفية (35.3%), في حين مجموعات المنخربات الملتصقة بنسبة اقل (19.4%). إن أكثر 10 اجناس وفرة هي: *Asterorotalia* (13.3%), *Quinqueloculina* (12.4%), *Bolivina* (9.8%), *Nonion* (8.6%), *Ammonia* (5.5%), *Textularia* (5.4%), *Elphidium* (5.2%), *Cibicides* (3.9%), *Challengerella* (3.6%) و *Hanzawaia* (3.4%). اكثر الأنواع الشائعة هي *Nonion* sp. 1 (5.5%), *Asterorotalia dentata* (5.0%), *Quinqueloculina* sp. 1 (4.8%), *Nonion* sp. 2 (4.5%), *Rotalinoides* cf. *R. gaimardii* (3.3%), *Asterorotalia* sp. 3 (3.2%), *Quinqueloculina* sp. 8 (3.1%), *Bolivina* cf. *B. persiensis* (3.0%), *Bolivina* cf. B. *striatula* (2.9%) و *Ammonia* sp. 1 (2.9%). أنا أفترض أن إستراتيجية التغذية , علي سبيل المثال سلوك (*Nonion, Ammonia, Elphidium* and *Asterorotalia*) يزيد من الرواسب الناعمة (الطين), توافر المغذيات والأكسجين, كلها عوامل تتحكم في تنوع وتوزيع المنخربات القاعية في الخليج. بسبب اهمية هذه المسطحات المائية في التغير المناخي العالمي, هذه الدراسة قامت بتحديث نوع وتوزيع مجموعات المنخربات القاعية.

CHAPTER 1

Introduction

Foraminifera, to be comprehensible by a non micropaleontologist and possibly a layman, are simply described here as single-celled, microscopic organisms similar to amoeba but possessing shells of various compositions (Jones, 2013). They are testate, granulo-recticulate protists, which are predominant in marine environments. Owing to their presence in ancient rock records and modern marine environments, foraminifera are excellent tools in sediment-age determination, rock-type correlation (local, regional and global scales) and interpreting ancient environments (Edgar, 2015). They are also very useful for paleoclimate reconstruction, paleoecology, civil engineering, stratigraphy, oil and gas (biosteering/biostratigraphy), ecology, environmental impact assessment, pollution and environmental contamination studies. There is a growing interest in the application of foraminifera for environmental monitoring programs of the world's coastal environments (Frontalini et al., 2009; Frontalini and Coccioni, 2011; Frontalini et al., 2011; Cosentino et al., 2013). This can be attributed to several factors including their relatively short life spans, growth rates, relatively small sizes, diverse species and cosmopolitan nature, and the ease of collecting statistically meaningful numbers per gram of sediment, which can be sampled quickly and inexpensively at minimal impact on the immediate environments (Hallock et al., 2003). They are widely used as proxies and indicators of several environmental parameters such as primary productivity, water depth, organic matter flux, methane release, and distribution of water masses (Steele et al., 2009). Foraminifera also provide proxy information of the spatio-temporal nature when observed as fossils, a unique feature when studying an impacted site "after the fact" especially in the absence of original baseline data (Scott et al., 2001).

1.1 Geography and Geological Setting

The Gulf is a late Pliocene to Pleistocene shallow tectonic depression, a result of the Zagros Orogeny, created by collision and compression between the Arabian and Asian plates. It is a marginal sea extension of the Indian Ocean, and covers an area of approximately 22,600 km^2 (Kassler, 1973; Seibold et al., 1973). It is elongated along its axis trending NW–SE; measures 1000 km in length, 300 km at its widest point, and 60 km where it is constricted by the Strait of Hormuz where it opens into the Indian Ocean (Purser, 1973; Murray, 1991). Its morphology is influenced by the interaction of the Arabian platform and Zagros folds, i.e., a relatively stable Arabian foreland flanking the Precambrian Arabian shield and subsiding below the unstable Zagros fold belt area (Kassler, 1973; Purser and Seibold, 1973). Compared to the rocky, mountainous terrain of the Iranian coast, the Arabian marine shelf is gentler, wider, and largely produced by salt diapirism or erosional relicts of the Quaternary (Kassler, 1973). The presence of the Qatar Peninsula, however, modifies the rather uniform Arabian coastline by changing the pattern of sedimentation and current movement in the southeastern sectors of the Gulf (Riegl and Purkis, 2012). The aforementioned shoreline is also characterized by sabkhas (evaporitic flats), supratidal areas, and extensive storm beaches in a more exposed setting. (Kassler, 1973; Purser and Evans, 1973; Purser and Seibold, 1973). The Gulf can be divided into two sedimentary realms based on predominant sediment types; autochthonous pure carbonate with siliciclastic admixture dominating the southern Arabian realm and the northern fluvial Iranian realm (Riegl et al., 2010). The sea floor of the Gulf is gently inclined towards the shelf break with an average depth of 35 m and maximum depth of 100 m at the Strait of Hormuz. The Gulf is arguably a classical example of a mixed carbonate–siliciclastic ramp system (Riegl et al., 2010). The submarine topography of the Gulf, which predominantly has very gentle sea-floor gradients and several bathymetric highs (especially in the south), also reflects the interaction of the Arabian Peninsula and Zagros mountains (Purser, 1973). Coupled with salt diapirism, the Gulf has >20 islands and several bathymetric highs (Kassler, 1973). The deeply submerged highs are important areas of foraminiferal sand accumulation particularly towards the basin axis (Riegl and Purkis, 2012). Depending on their origin, i.e., due to the Zagros orogeny or salt tectonics by the Hormuz salt, the bathymetric highs can be classified as coastal or basin central types (Purser, 1973; Riegl and Purkis, 2012). Kassler (1973) noted that sediment type in an area is controlled by its biological communities. However, the submarine topography dictates the sediment thickness. Sparker records show that sediment thickness is least on topographic highs, and greatest in depressions (Purser, 1973). The Shatt Al-Arab river delta forming the northwest shoreline and many rivers along the Zagros mountain area in coastal Iran forming the eastern flank, deliver significant amounts of terrigenous sediment and greatly influence the sedimentology of the Gulf (Purser and Seibold, 1973a; Alsharhan and Kendall, 2003). Several rivers originating from the Zagros mountain area run into the Gulf and are characterized by frequent "flash-floods". Notable among these rivers are Arvand Rud (Shatt Al-Arab), Gamasb, Karun, Jarahi, Zohreh, Dalaki, Mend, Shur, Minab, Mehran and Naband. Rivers discharge mud and fine sand, consequently the sediment off the Iranian coast is dominated by marl and the carbonate content increases away from this coast (Seibold et al., 1973). Many of the sedimentary parameters in the eastern sector of the Gulf can be directly linked to the Iranian river mouths (Kassler, 1973; Purser and Seibold, 1973). The Gulf is situated in an arid, subtropical climate region experiencing extremes of summer temperature and salinity due to its enclosed nature. The range for water temperatures in offshore areas of the Gulf are 20–32°C (Clarke and Keij, 1973), western gulf; 16–36°C (John et al., 1990), while in lagoonal areas the range is 15–40°C (B. Purser and Seibold, 1973; Joydas et al., 2015). Figures 1–12 present regional maps of the Arabian Gulf area with the sea surface temperature (SST) changes for January–December 2015 from data obtained from National Aeronautics and Space Administration (NASA)'s Earth Science Data Systems (EOSDIS) WorldView Program.The tides are complex and range from diurnal, semi-diurnal to mixed (Riegl et al., 2010). Wind direction is mostly from the northwest, caused by the seasonal Shamal "north" wind (very strong in the winter) throughout the year. Wind is an important physical factor; it accounts for appreciable amount of siliciclastic sediment input into the Gulf (Riegl et al., 2010), i.e., aeolian sediments. Due to the shallow nature of the Gulf, almost all parts of the Gulf are within the photic zone with a few exceptions along the Iranian Coast (Murray, 2006). Rainfall is scare (3–8 cm/y) while evaporation rates (140–500 cm/y) are high and associated with the prevalent high temperatures, strong winds, and low precipitation (Reynolds, 1993). Salinity (Figure 13) is marked by a seasonal gradient both horizontally and vertically, largely due to minimal oceanic buffering (Reynolds, 1993). The Gulf can be split into two realms, based solely on surface-water salinity differences: a northern, less saline realm and a southern more saline realm owing to inflowing surface waters from the Arabian Sea through the strait of Hormuz that have a salinity of about 36.5‰. This value increases rapidly to about 40‰ in mid Gulf and drops to about 36.5‰ at the Shatt Al-Arab due to dilution from freshwater input (Riegl et al., 2010; Sheppard et al., 2010, 1992). There is also a marked west to east gradient along the Gulf axis, with the Arabian side becoming more saline. In some lagoons and embayments southeast of Qatar, salinity can exceed 50‰ (Murray, 1970a), while in Half-Moon Bay on the Saudi coastline we have measured salinity in excess of 60‰.

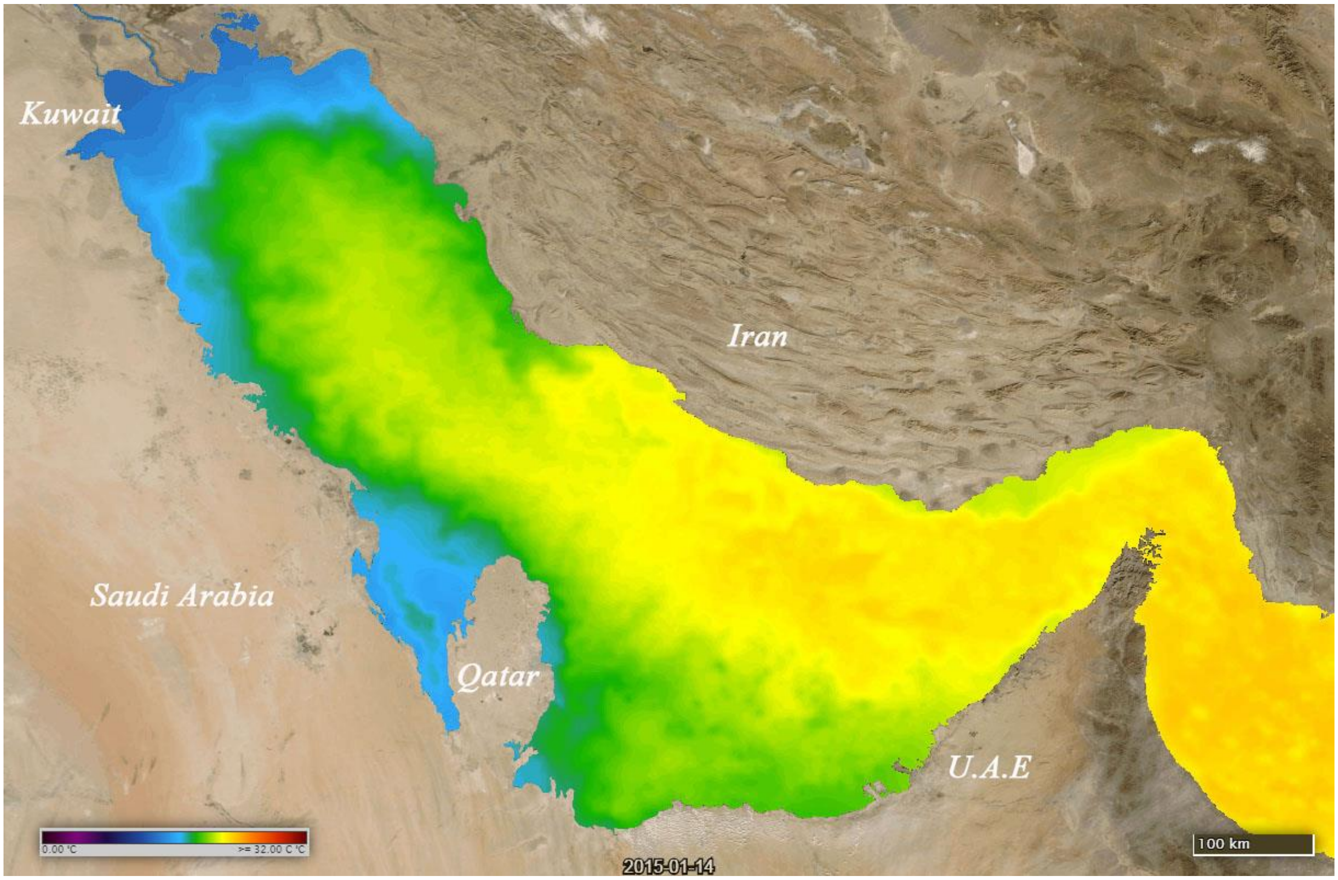

Figure 1. SST for January 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

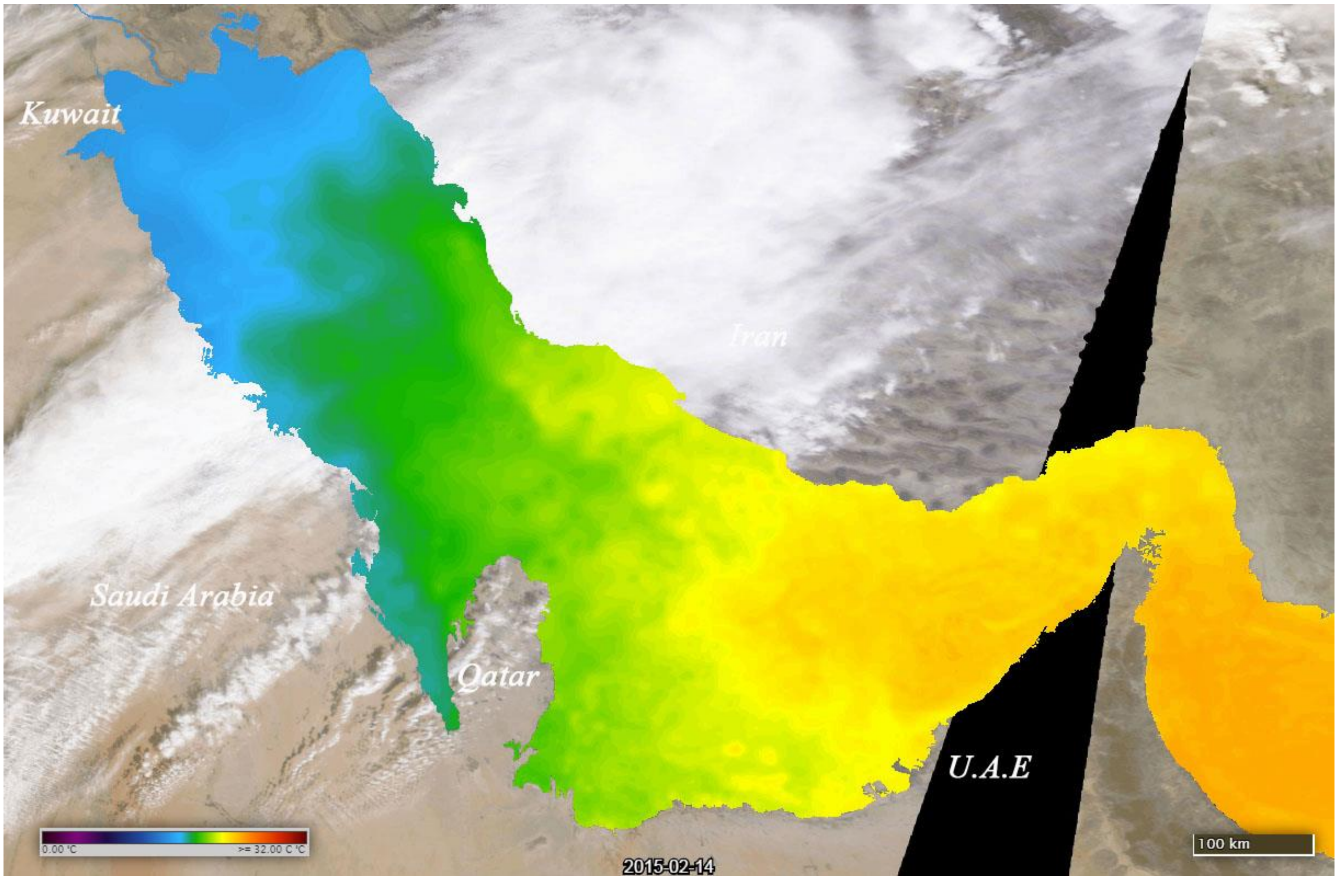

Figure 2. SST for February 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

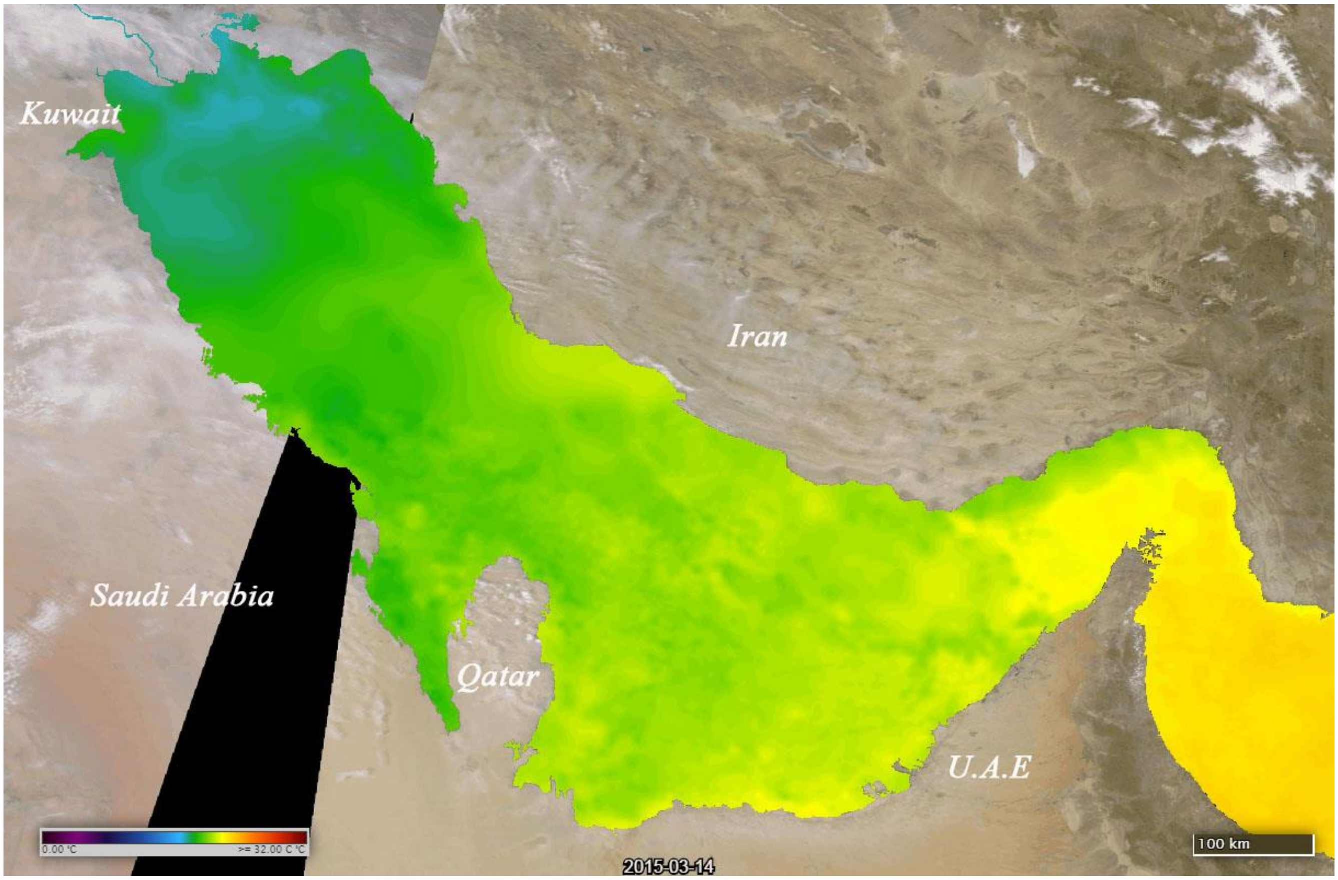

Figure 3. SST for March 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

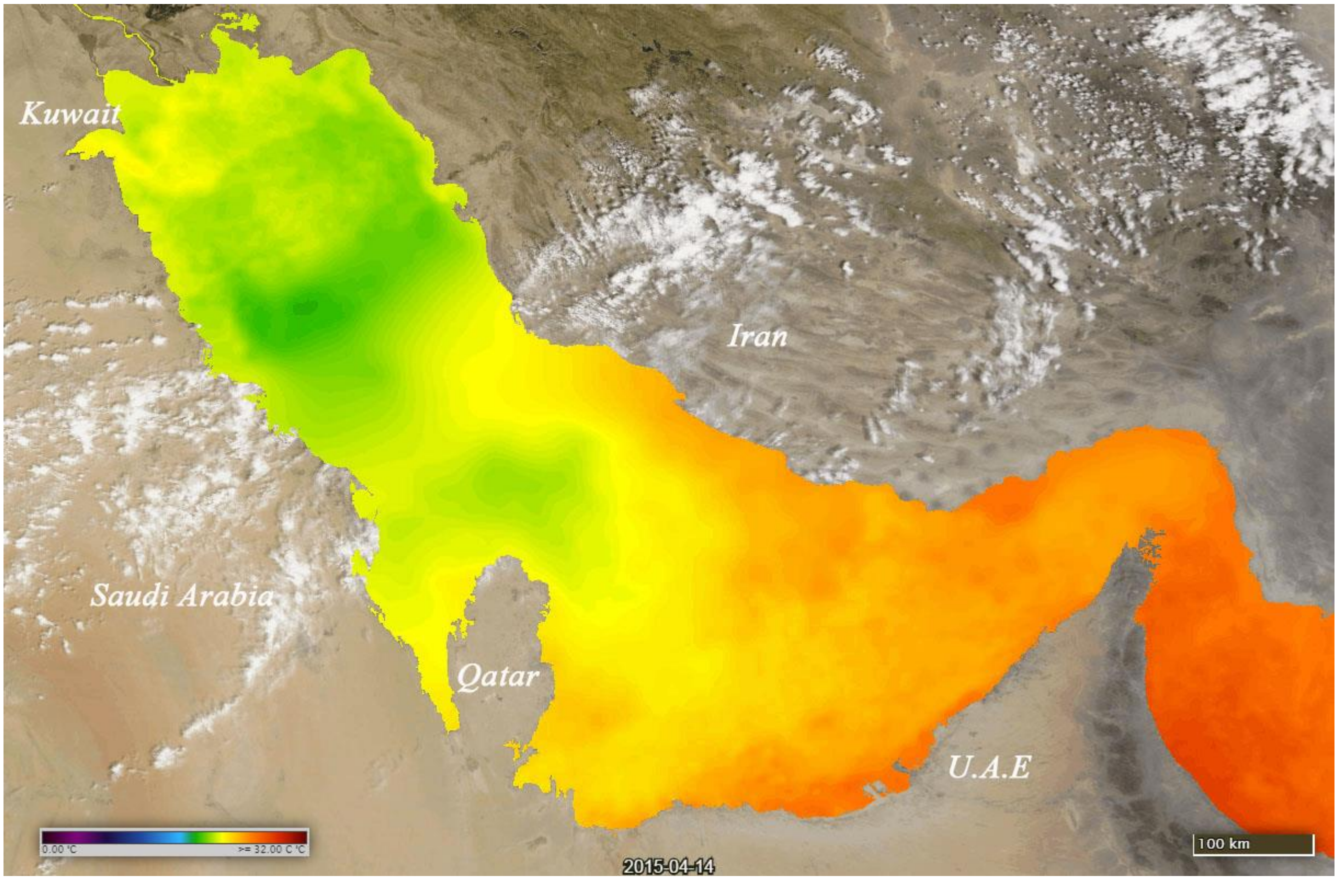

Figure 4. SST for April 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

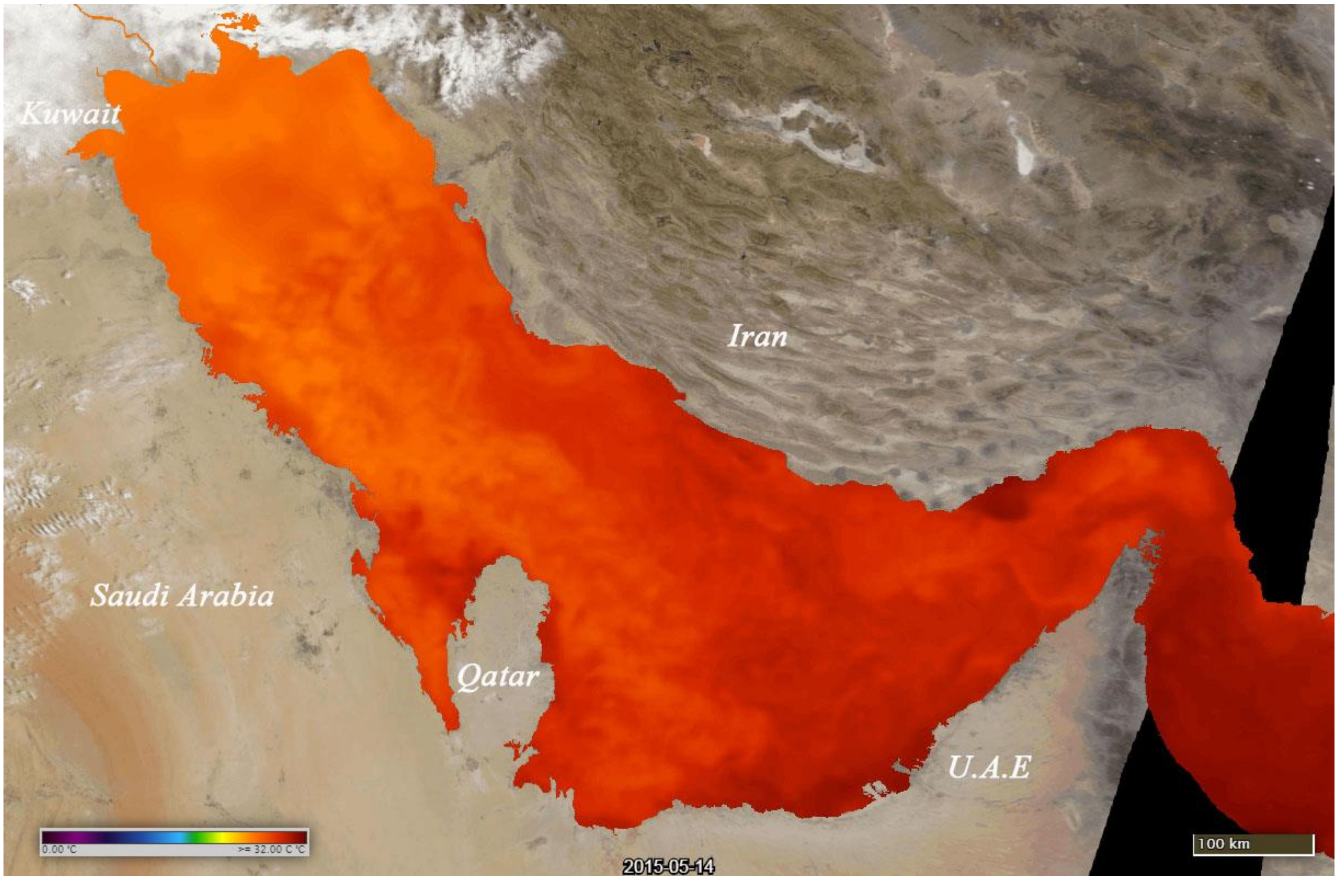

Figure 5. SST for May 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

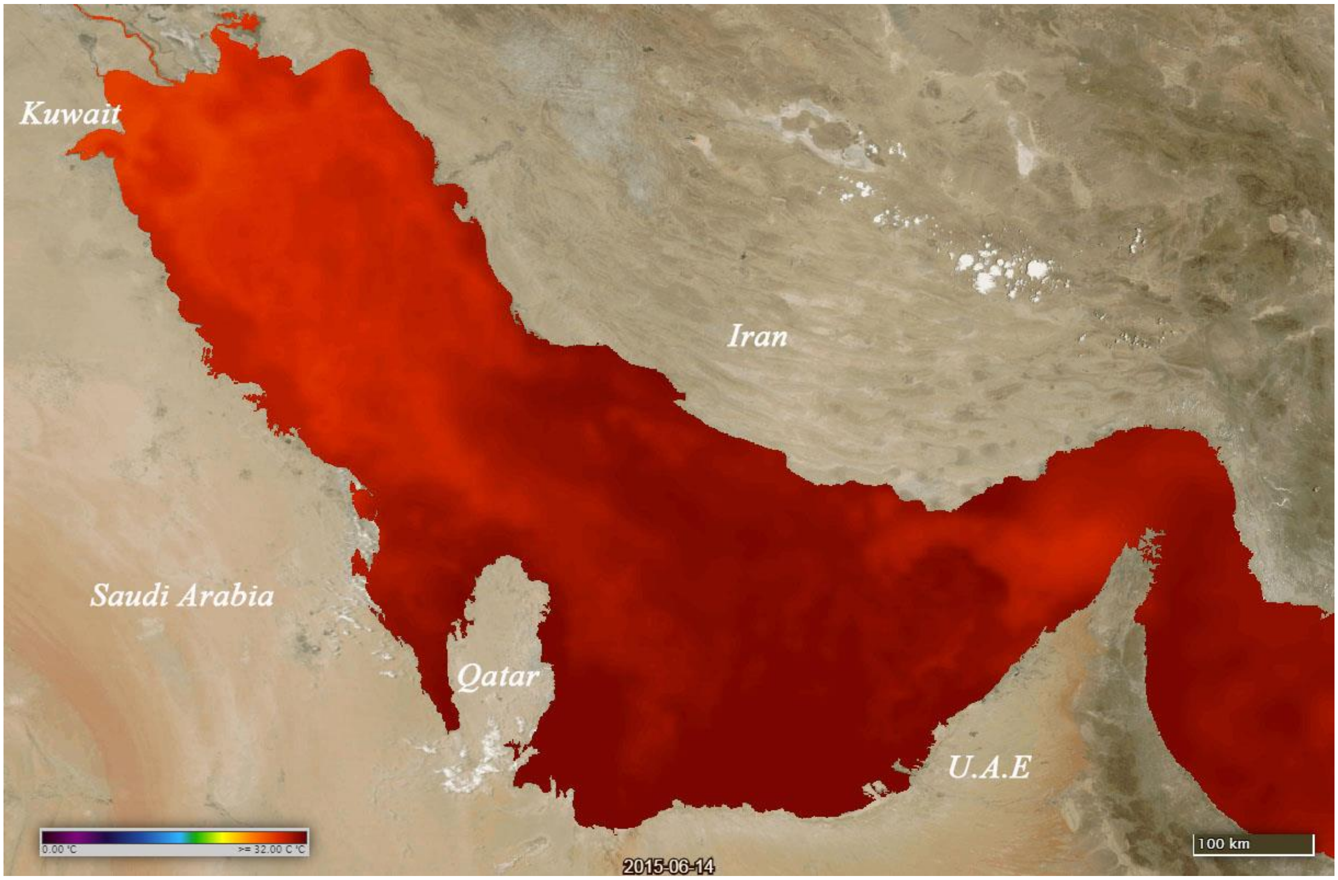

Figure 6. SST for June 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

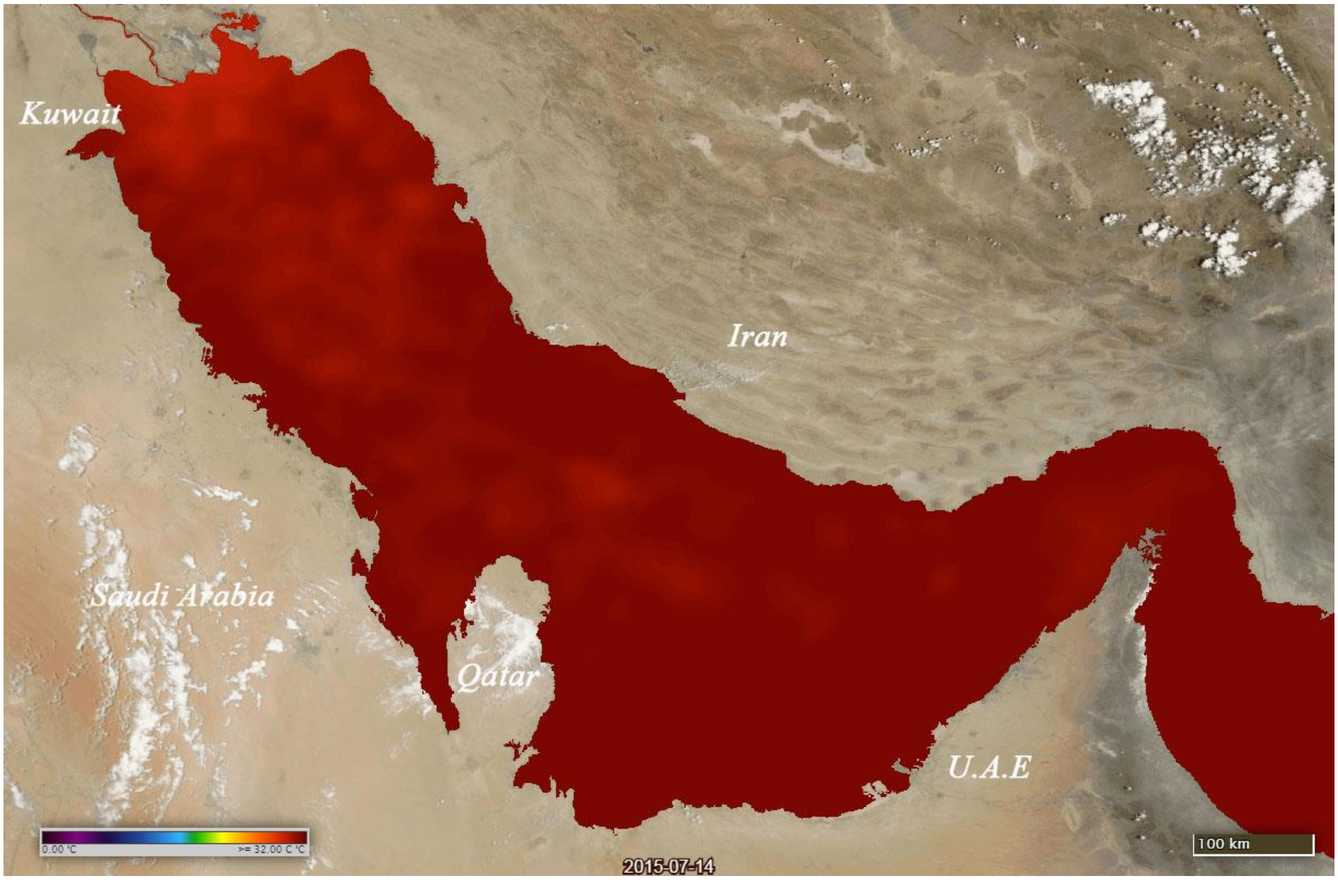

Figure 7. SST for July 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

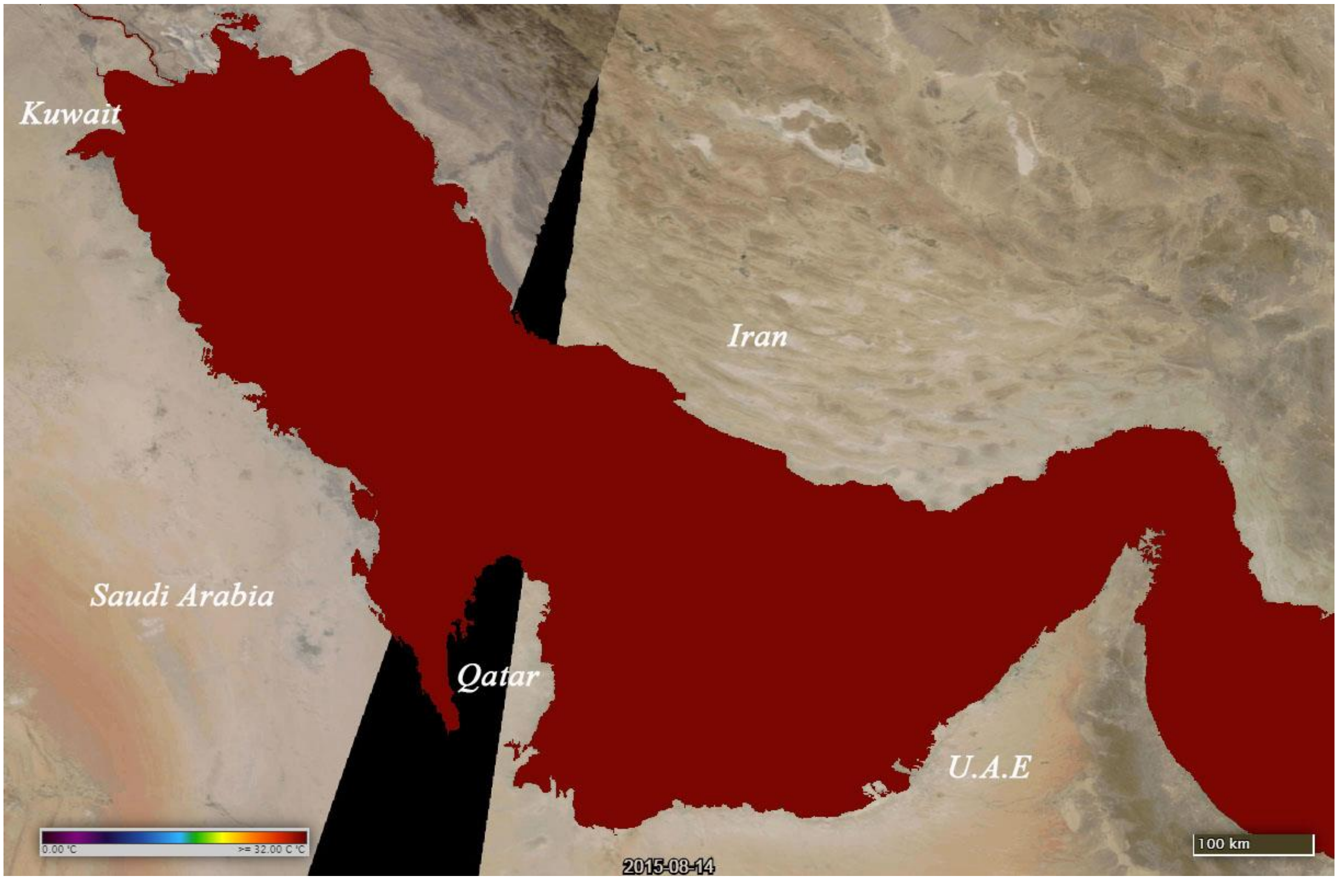

Figure 8. SST for August 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

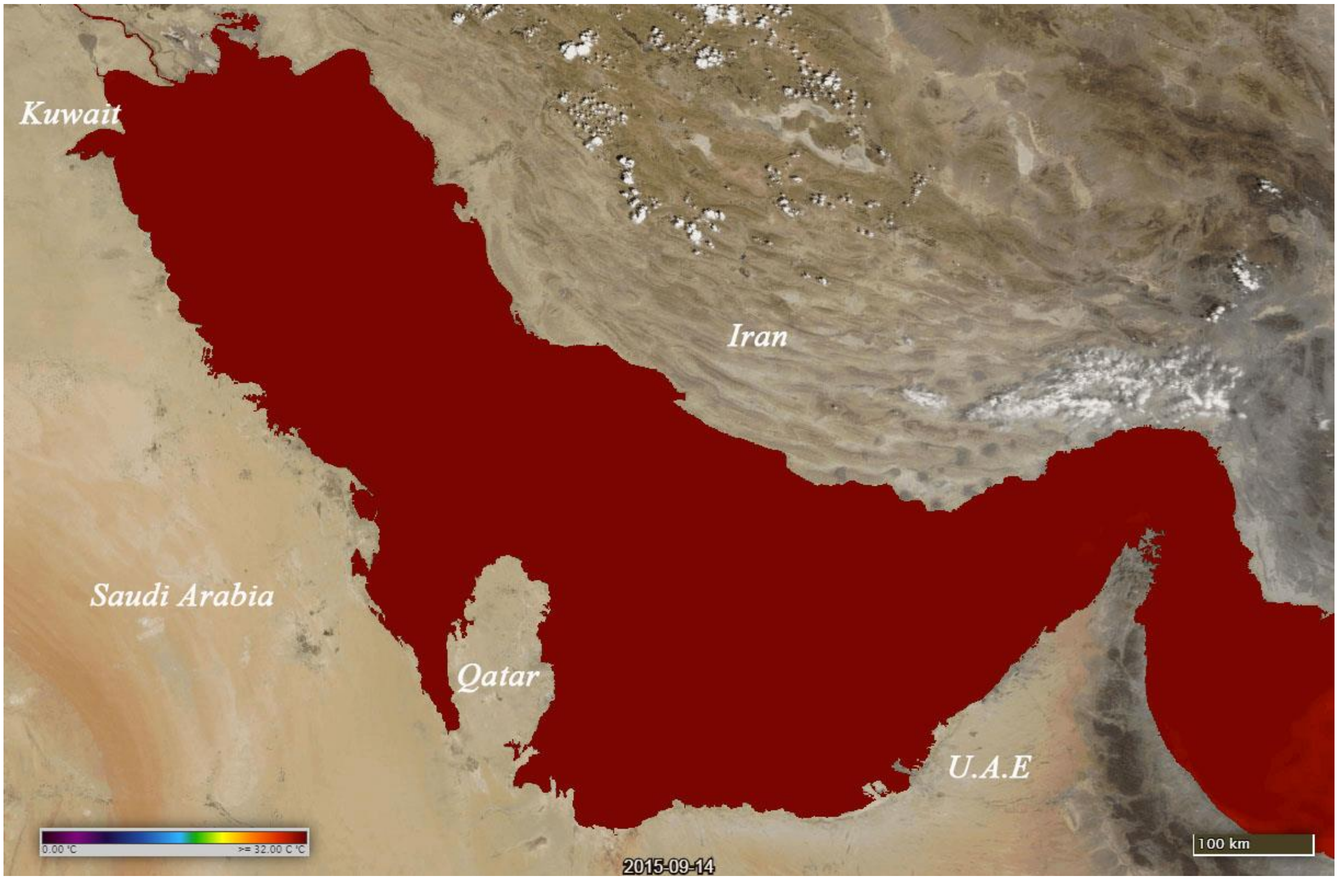

Figure 9. SST for September 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

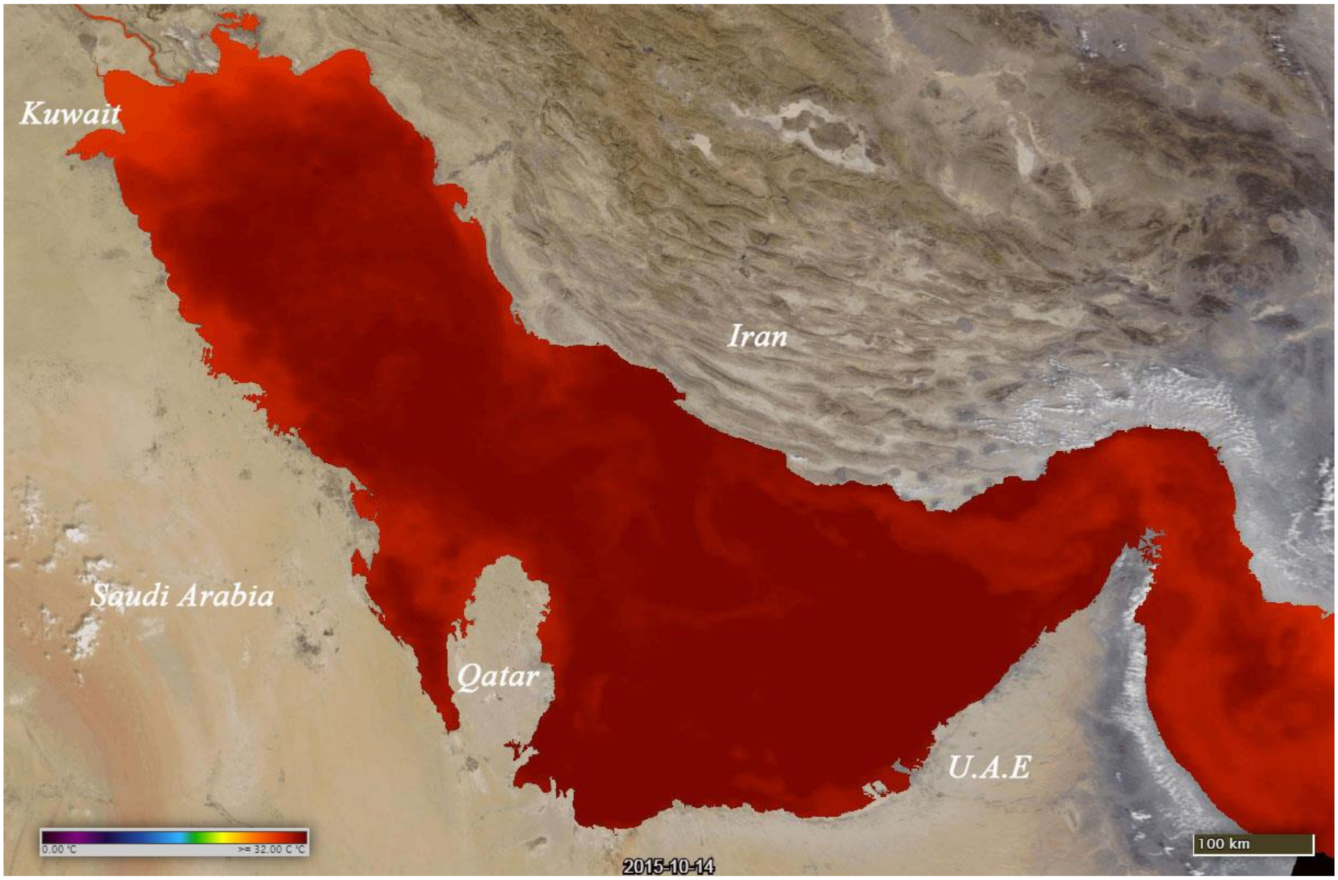

Figure 10. SST for October 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

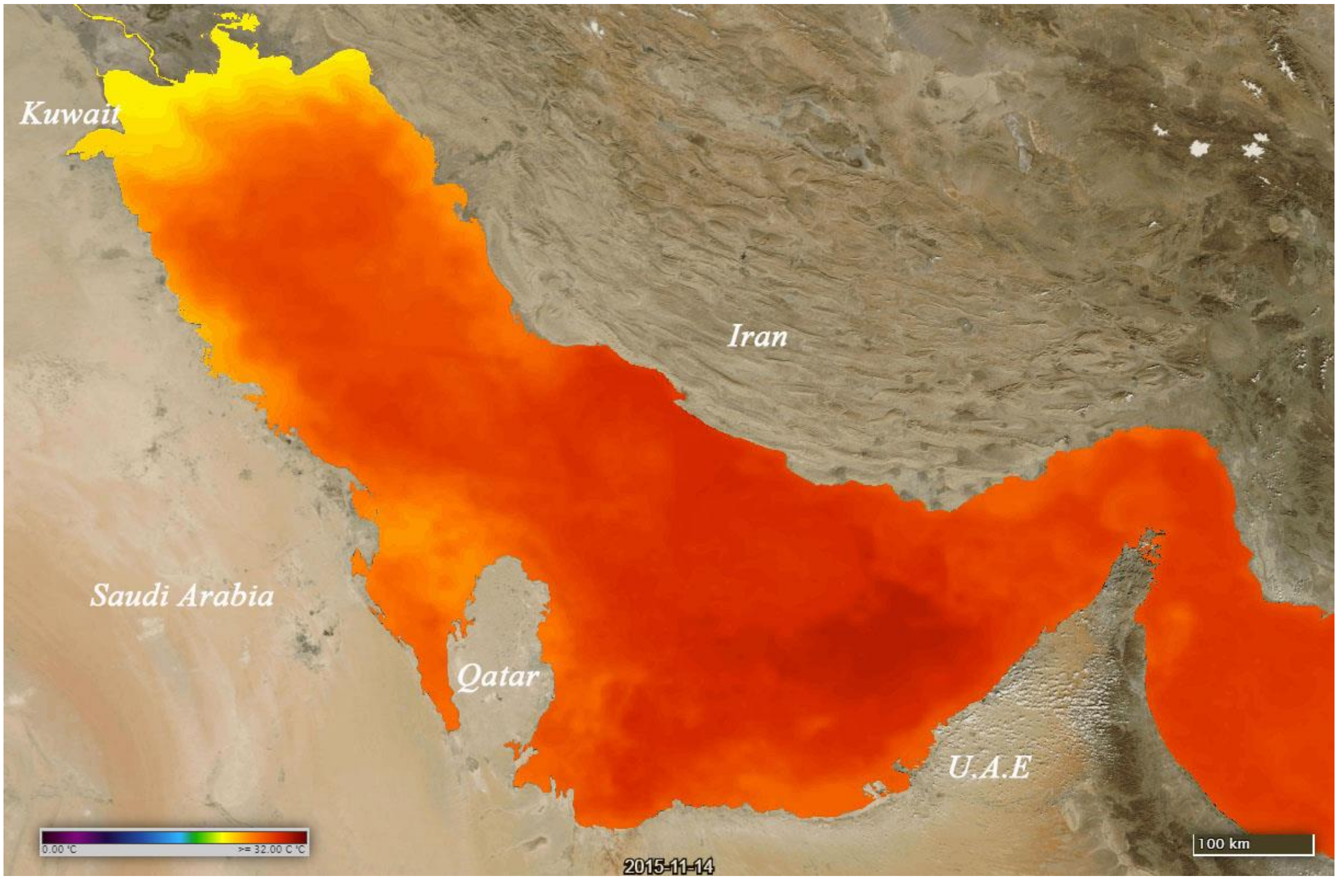

Figure 11. SST for November 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

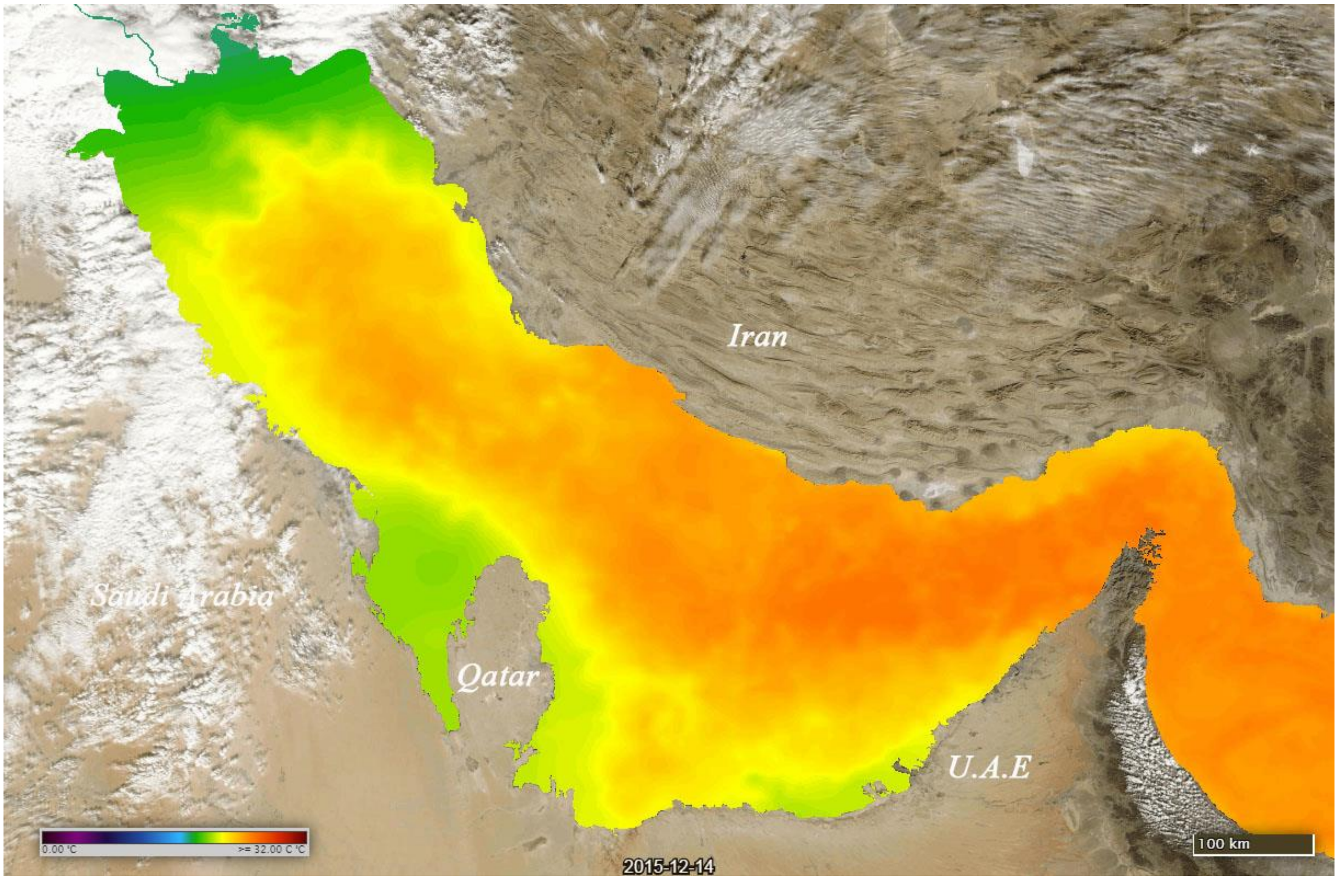

Figure 12. SST for December 2015 over the Arabian Gulf, data obtained from NASA's EOSDIS Worldview Service.

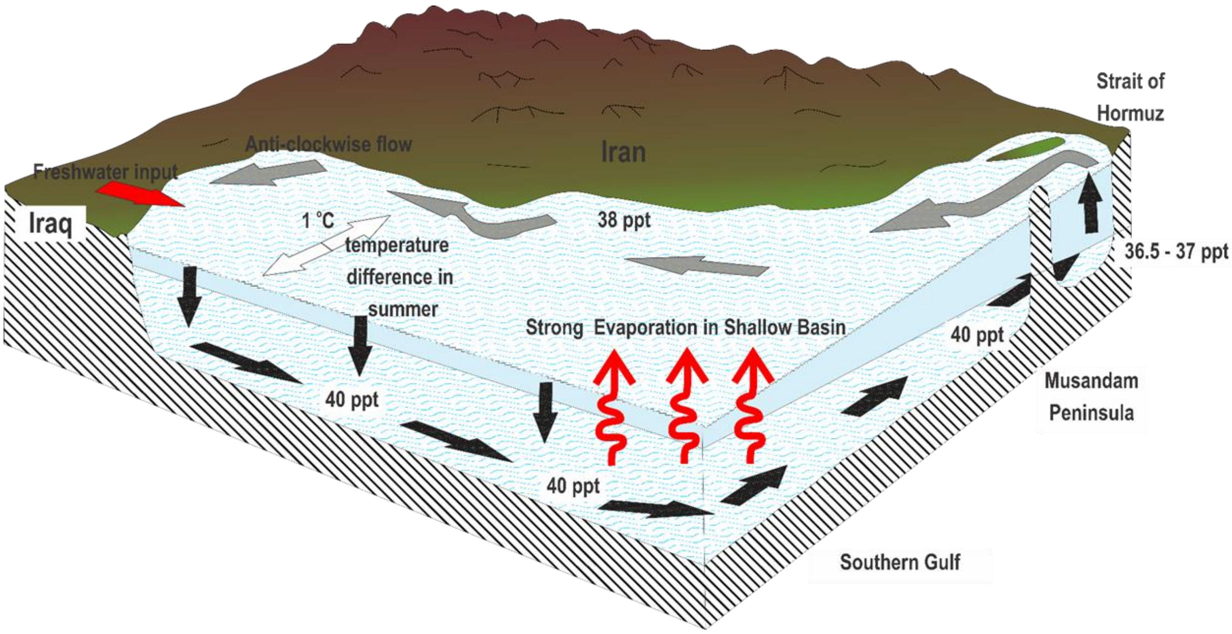

Figure 1. Major current flows in the Gulf [modified after Sheppard et al. (2010)], showing mechanisms causing the density gradient in the Gulf and the flow through the Straits of Hormuz. Grey arrows are incoming surface water from the Indian Ocean. Dark arrows are a denser, deeper water flow while the red indicate fresh water inputs. Light shading in Gulf shows ''wedge" of water of increasing density.

CHAPTER 2

Literature Review

Studies on benthic foraminifera in the Arabian Gulf dates back to the early 1960's, just before the oil boom. In a series of papers considering ecology, distribution and systematics of foraminifera from locations in southern Arabian Gulf (i.e., Abu Dhabi, Khor al Bazam, and Halat al Bahrani), Murray (1965a, 1965b, 1966a, 1966b, 1966c, 1970a) recognized 58 species of benthic foraminifera belonging to 34 genera, 24 families, 18 superfamilies and six orders. Most of the taxa encountered, especially *Quinqueloculina* and *Triloculina* where left in open taxonomy probably due to the lack of known taxa with similar features for comparison. Murray (1970b), documented 23 living foraminifera from Abu Dhabi region using the Rose Bengal-Ethanol technique and attributed low diversity and high individual numbers to the extreme environmental conditions (salinity and temperature) in the sampled area. Lutze et al. (1971) studied the sediment fraction and population density of living larger foraminifera (i.e., *Amphistegina* sp., *Heterostegina* sp. and *Operculina* sp.) in the Arabian Gulf and concluded that large benthic foraminifera might be responsible for 150 g year^{-1} m^{-2} in carbonate production. Lutze (1974a) studied 134 samples collected from the Iranian parts of the Arabian Gulf and concentrated on agglutinated and hyaline groups (Lutze, 1974b, 1974c). The author recognized 52 species, 7 "species groups" and 2 new species. The "species groups" are composed of several species requiring additional taxonomic studies. Haake (1975) studied a subset of 129 samples collected from the same location as Lutze (1974a) and described the porcelaneous benthic foraminifera component and recognized 54 miliolid species. Clarke and Keij (1973) documented the distribution of foraminifera in the southwestern parts of the Gulf and noted that the foraminiferal assemblages consist of almost entirely *Peneroplis* and with a high proportion of aberrant tests in restricted environments. However, the authors also noted that their scope of work was not focused on the detailed taxonomy of foraminifera and that they selectively considered the large benthic foraminifera. Ahmed (1991) documented the distribution of benthic foraminifera from Tarut bay in the western part of the Gulf and reported 43 species dominated by miliolid assemblages. The author noted significant variations in assemblage composition within sub environments (i.e. intertidal, shallow subtidal, and deeper subtidal zones). El-Deeb (1992) noted the distribution of benthic foraminifera in a study conducted in coastal areas of the United Arab Emirates in southwestern Arabian Gulf and documented 16 species dominated by miliolid foraminifera. In a two-year monitoring study conducted in Bahrain, Basson and Murray (1995) reported the changes in the annual production of tests and species diversity for *Ammonia beccarii*, *Elphidium advenum*, *Brizalina pacifica* and *Nonion* sp. The study provided an insight into the seasonality and randomness associated with the reproductive cycles of benthic foraminifera in a hypersaline environment. In southern Kuwait, at the northern-most reach of the Gulf, Al-Zamel et al. (1996) reported 42 benthic foraminiferal species from intertidal and tidal channels of two interconnected tidal creeks. Cherif et al. (1997) reported 94 foraminiferal species (benthic and planktonic) for the entire Gulf, covering a wide range of environments mostly in offshore areas. Compared to the number of benthic foraminiferal species (350) in the Gulf of Aqaba (an extension of the Red Sea) identified by Hottinger et al. (1993) and 1000 species in the Mediterranean Sea (Frontalini et al., 2015), Cherif's numbers are quite low. The benthic foraminiferal species identified by Cherif et al. (1997) are represented by 53 genera, 30 families, 18 superfamilies and five orders dominated by three rotaliid species *Ammonia* cf. *aberdoveyensis* (9.7%), *Challengerella bradyi* (9.3%) and *Asterorotalia dentata* (8.9%). In the most northern part of the Gulf along the western Mesopotamian shelf, an area largely influenced by the largest source of fresh water into the Gulf, Al-Zamel and Cherif (1998) reported 46 species of benthic foraminifera, which were dominated by the rotallids. Hitmi and Hitmi (2000) conducted a survey of benthic foraminifera in the eastern and northern sides of Qatar Peninsula using several linear transects and reported 50 species of benthic foraminifera. The assemblage was dominated by miliolids, constituting over 45% of the total of all groups. Sohrabi and Sahba (2010) studied the distribution of benthic foraminifera collected from the Qeshm Island (southeast Gulf) in an area with mangrove vegetation. A total of 54 species were reported belonging to 27 genera. In an environmental pollution monitoring study, Al-Zamel et al. (2009) studied the benthic foraminifera composition of Sulaibikhat Bay (Kuwait), an area greatly impacted by anthropogenic sources of pollution. They correlated marked differences in the community structure and composition of 45 benthic foraminifera to levels of pollution in the bay area and established a gradient between the shallow tidal mudflats and the deep tidal channel. Sohrabi and Sahba (2010) correlated the diversity and abundance of 19 taxa of benthic foraminifera to levels of contaminants in sediment collected from Asalooye coastline in a petrochemical plant outfall zone. Mooraki et al. (2013) reported the distribution of 7 taxa of benthic foraminifera from samples collected from Nayband Bay and Haleh Estuary along the Iranian coastline. Based on 26 samples collected in 2016 from the northwestern parts of the Gulf, Nabavi et al. (2014) documented the distribution of 93 benthic foraminifera collected from depths of 33–77 m. Recent studies on a carbonate ramp off the coast of Kuwait by Parker and Gischler (2015), documented the presence of 141 species belonging to 51 genera, 27 families, 19 superfamilies and four orders. The authors reported five assemblages varying from shallowest to deepest areas; *Peneroplis–Elphidium crispum*, Miliolid, Miliolid–*Elphidium*, *Elphidium–Nonion*, *Asterorotalia–Elphidium* (i.e., there is an onshore–offshore pattern). In an integrated study using trace elements, organic matter, sediment texture, etc., Al-Enezi and Frontalini (2015) documented the composition and community structure of 59 benthic foraminifera taxa in the in Sulaibikhat Bay (Kuwait). They reported a high level of trace metal pollution in the eastern part of the bay and western side is also characterized by relatively high concentrations of total organic carbon. The lowest benthic foraminiferal diversities were found near the Al-Shuwaikh port, which correlated with the highest pollution levels recorded in the area. Recently, Arslan et al. (2015) documented spatial and temporal variation of four benthic foraminiferal taxa (*Ammonia* and *Glabratellina*, *Peneroplidae* and *Elphidium*) in a relatively unpolluted site in Bahrain. Arslan et al. (2016) reported the exclusive presences of *Ammonia* and *Elphidium* in a characteristic siliciclastic coastal environment along the eastern coast of Saudi Arabia. In a restricted lagoon in Bahrain, Amao et al. (2016) identified 136 species, 25 genera, 15 families, 10 superfamilies and four orders. The lagoonal species were dominated by *Peneroplis pertusus*, *Ammonia convexa*, *Coscinospira hemprichii*, and *Elphidium advenum*.

Based on the review of the papers discussed above, many species of benthic foraminifera have been reported in open nomenclature or are only tentatively identified. This situation is likely to change, as there is a concerted effort by the micropaleontology group at King Fahd University of Petroleum and Minerals to describe and document new and endemic species (Amao et al., 2016a, 2016b; Amao and Kaminski, 2016). Historical sampling sites and some locations sampled in this research are shown in Figure 14.

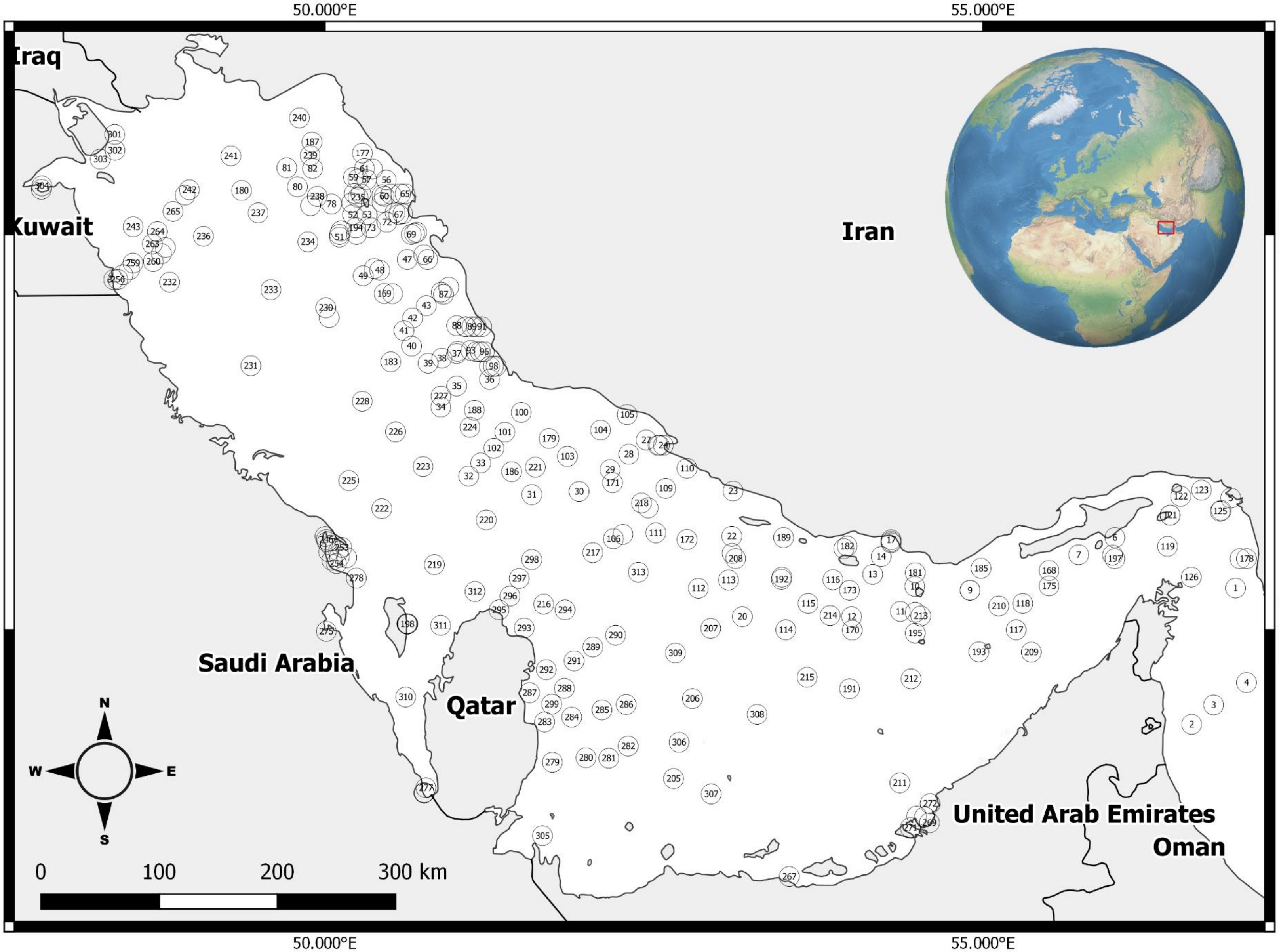

Figure 2. Previously studied locations in the Arabian Gulf Sampling area map with region overview map showing extent of the Gulf and bordering countries

CHAPTER 3

Morphological Abnormalities in Benthic Foraminifera Caused by an Attached Epibiont Foraminifer

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SUMMARY-- This study focused on the possible 'parasitism-like' relationship between the epibiont *Cymbaloporetta* sp. and basibiont benthic foraminifera including *Agglutinella soriformis*, *Adelosina carinatastriata*, *Pseudotriloculina* sp. and *Spiroloculina indica* from a sample collected off the east coast of Bahrain in the Arabian Gulf. There are no indications of preferential host selection, the epibiont seems to attach onto any available basibiont. However, constriction of the test and subsequent growth of the basibiont's chambers at the point of attachment of the epibiont might suggest an early link in their ontogeny. This biotic relationship has implications on the basibionts' development and ontogeny that eventually results in the development of foraminiferal abnormalities. The finding of morphological test abnormalities caused by an epibiont in an unpolluted environment has important implications for the use of the abnormalities for pollution biomonitoring. Samples from other areas of the Arabian Gulf need to be studied to determine the background proportion of specimens with epiboints.

3.1 Introduction

Benthic foraminiferal morphological variations and abnormalities are known to be induced by either fluctuations of environmental parameters including changes of carbonate saturation state, temperature, salinity, depth, dissolved oxygen, mechanical damage and pollution (i.e., Boltovskoy et al., 1991; Yanko et al., 1994, 1998; Geslin et al., 2002). Epibionts (epizoic and epiphytic) and bioeroding foraminifera appear to be well documented in the literature (Langer, 1993; Langer and Bagi, 1994; Vénec-Peyré, 1996) but little is known about their role in formation of morphological abnormalities. This short communication documents a symbiotic relationship between an epibiont, *Cymbaloporetta*, and several basibiont benthic foraminiferal species and the possible induction of morphological abnormalities. Parasitic behaviours and epibiont-basibiont species relationships of foraminiferal taxa have been also documented in the geological record, for instance, during the Late Cretaceous by *Talpinella cunicularia* (Baumfalk et al., 1982). However, no study on recent foraminifera has quantitatively assessed this possible morphological abnormality-induction relationship. *Cymbaloporella tabellaeformis* has already been inferred to be a parasite (Matteucci, 1980). Other foraminiferal parasitic taxa might possibly include *Floresina*, *Rosalina*, *Fissurina marginata* (reported as *Entosolenia marginata*), *Cibicides refulgens*, and *Planorbulinopsis parasitica* (i.e., Le Calvez, 1947; Todd, 1965; Banner, 1971; Alexander and DeLaca, 1987; Cedhagen, 1994; Hallock and Talge, 1994).

3.2 Methodology

3.2.1 Sample Location

The study area is on the eastern coast of Bahrain in the Arabian Gulf (Figure 15). The Arabian Gulf is notable for extremes in temperature and salinity, which provides an excellent natural laboratory to study the interplay between various ecological parameters, more importantly the deterioration of the benthic environment due to rapid urban development and pollution sources (Sheppard et al., 2010). I measured salinity and water temperature for the area between June 2014 and April 2015 and the range recorded was 43–45 ppt and 26–28°C, respectively. The study area has been described by Arslan et al. (2015), who analysed organic and inorganic pollutants, and determined it is a relatively unpolluted site.

3.2.2 Sample Collection and Processing

Surficial sediment (20 ml) was collected using a piston syringe that penetrated 2 cm deep into the sediment. The location is on the foreshore and ≈ 100 m from the coastline, at a water depth of 65 cm (Fig. 1). The sediment sample was preserved using laboratory-grade ethanol (70%) with Rose Bengal stain. The sediment was left in the Ethanol-Rose Bengal mixture for two weeks before it was washed and wet-sieved through a 63 µm mesh sieve. It was dried and then used for benthic foraminiferal specimens' picking. The dried sample was sieved through a 125 µm mesh sieve, separated into two aliquots with approximately 300 specimens using a microsplitter to ensure statistically representative counts. The analysed sample is part of a larger collection of samples for a temporal and spatial study in the area. Selected specimens were imaged by using scanning electron microscopy (SEM). A modified resin embedding technique (Golubic et al., 1970), which is based on two component epoxy resins allowing faster setting of the resin and limiting the penetration into the foraminiferal test, was used. The resin casts were further grinded on a smooth glass with abrasive powder (#1000). After achieving the appropriate length, resin casts were placed in an ultrasonic water bath for 30 seconds to remove abrasive powder residue and then dried under an incandescent lamp. The resin cast provides support for handling the specimen and also enables desirable precise smoothness to be achieved. The faunal reference slides are currently housed in the author’s collection at KFUPM. These will be permanently archived in the European Micropaleontological Reference Center at Micropress Europe in Kraków (Poland).

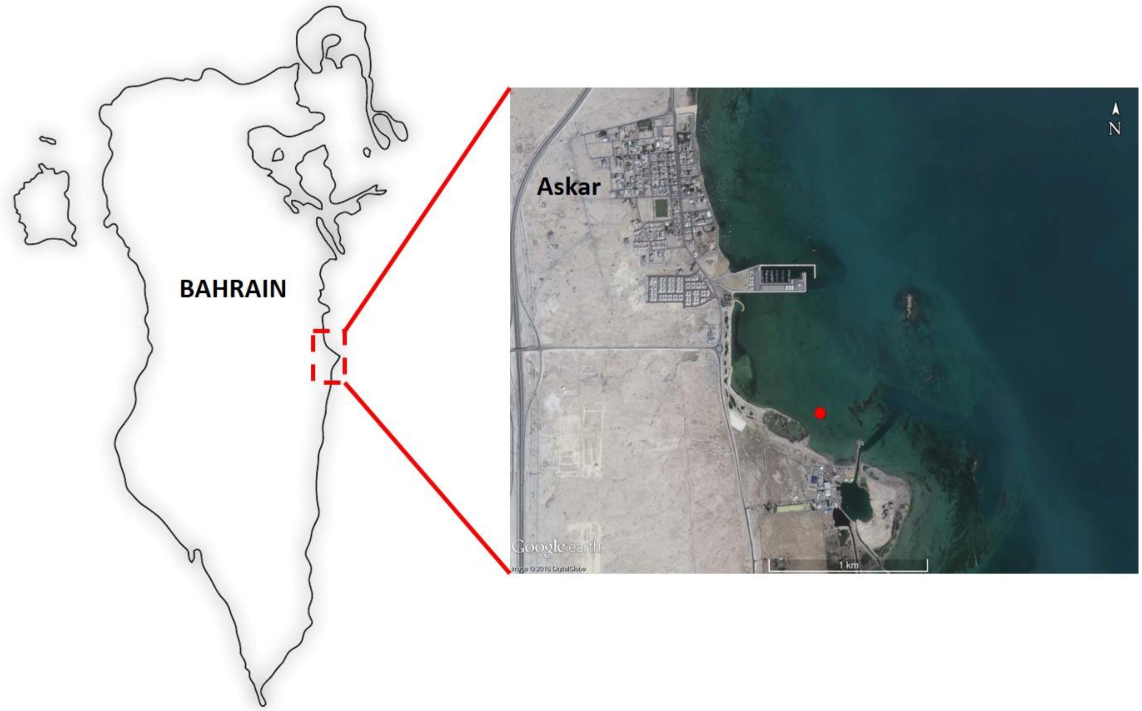

Figure 15. Location of the sampled station indicated by the inserted solid circle on the right image (26°02'40.1"N, 50°37'35.2"E)

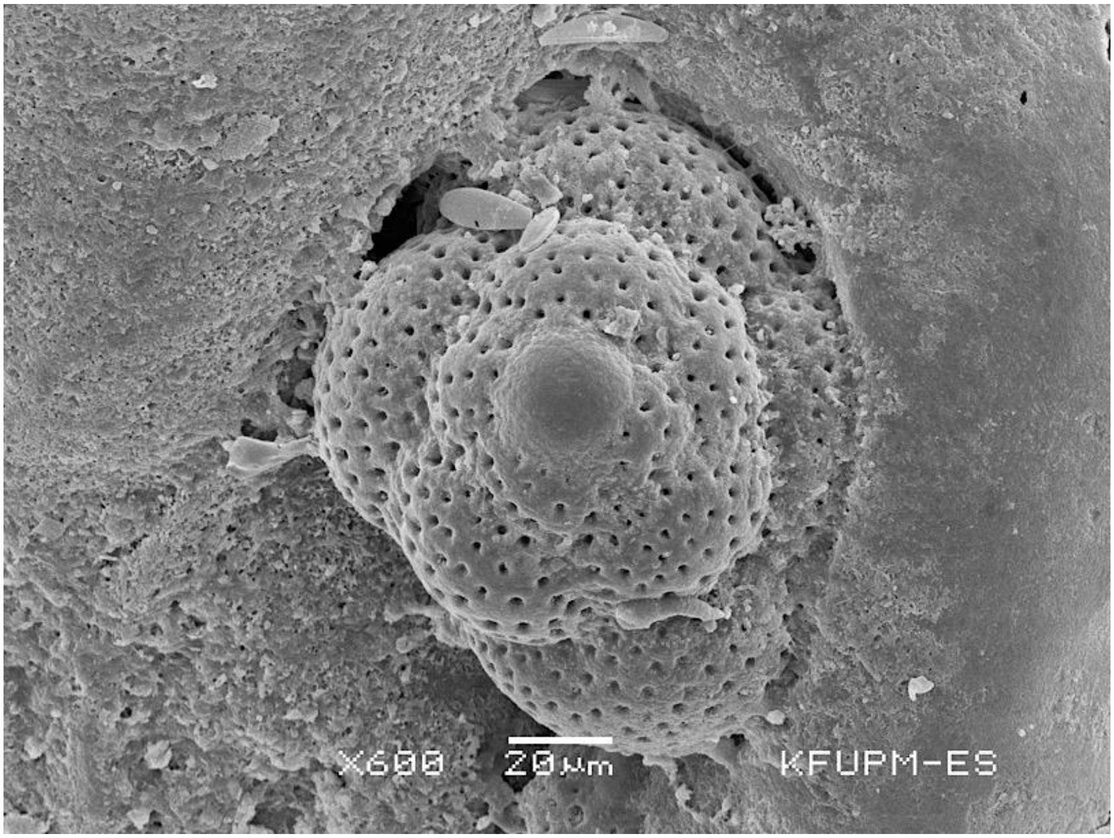

Figure 3. ***Cymbaloporetta*** **sp. embedded in the wall of** ***Adelosina carinatastriata*** **Wiesner, 1923.**

Figure 4. ***Agglutinella soriformis*** **El-Nakhal, 1983 (a) apertural view (b) lateral view of more evolute side (c) lateral view of more involute side** d-f ***Adelosina carinatastriata*** **(Wiesner, 1923), (d) lateral view of more evolute side (e) apertural view (f) lateral view of more involute side** g-i ***Pseudotriloculina*** **sp. (g) lateral view of more evolute side (h) lateral view of more involute side (i) apertural view** j-l ***Spiroloculina indica*** **Cushman & Todd, 1944. (j) apertural view (k) lateral view (l) lateral view opposite side of** k **with attached epibiont. All scale bars are 100 µm.**

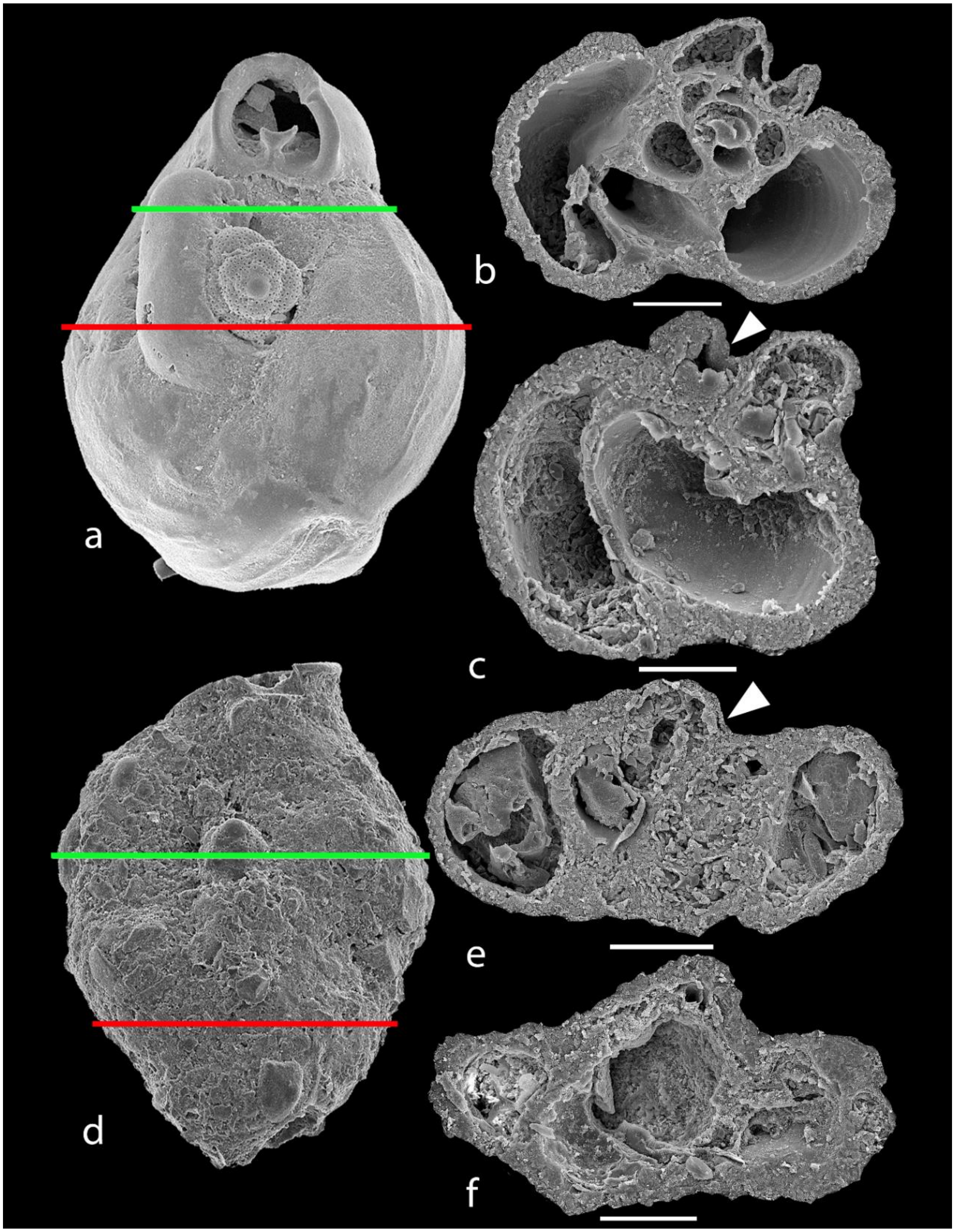

Figure 5. ***Adelosina carinatastriata*** **with two lines depicting the cross sections in green (b) and red (d).** b. **Cross of (a) from the anterior part, as indicated by the green line.** c. **Cross section of (a) from the posterior parts as indicated by the red line.** d. ***Agglutinella soriformis*** **with two lines depicting the cross sections in green (e) and red (f).** e. **Cross of (d) from the anterior part, as indicated by the green line.** f. **Cross section of (d) from the posterior parts as indicated by the red line. Inserted solid white triangle tips in (c) and (e) point towards the epibiont attachment. All scale bars where provided are 100 µm.**

3.3 Results

Foraminiferal specimens (1.9% or 11 out of 567 specimens) exhibit varying degrees of morphological abnormalities as a possible result of a symbiotic association between an attached epibiont foraminifer and its basibiont foraminiferal host. SEM images revealed test morphological abnormalities found at spots characterized by the exclusive occurrence of the epibiont *Cymbaloporetta* sp. (Figure 16). The host species include *Agglutinella soriformis* El-Nakhal, 1983 (Figure 17a–c), *Adelosina carinatastriata* (Wiesner, 1923) (Figure 17d–f), *Pseudotriloculina* sp. (Figure 17g–i) and *Spiroloculina indica* Cushman and Todd, 1944 (Figure 17j–l) and most of them show various degrees of morphological abnormalities. The apertural view of *Agglutinella soriformis* (Figure 17a), on the more evolute side, shows the stunted growth of the middle chamber, i.e., *Cymbaloporetta* sp. is attached on the chamber as opposed to having been "agglutinated" by the basibiont. *Adelosina carinatastriata* (Fig. 3d–f) is severely malformed, with the epibiont deeply embedded within the test of the basibiont and likely promoting the modification of the shape and coiling directions of all the chambers. *Pseudotriloculina* sp. (Figure 17g–i) appears to have accommodated the epibiont with minor modification. In *Spiroloculina indica* (Figure 17l), on the more evolute side, there is an abrupt change in the direction of the final chamber, with the epibiont embedded towards the posterior end. Cross sections taken at two planes through *Adelosina carinatastriata* (Figure 18a–c) show test abnormalities as a result of the host accommodation of the epibiont. *Agglutinella soriformis* (Figure 18d–f) also exhibits abnormal chambers at the point of epibiont attachment.

3.3.1 Systematic Descriptions

Genus *Cymbaloporetta* Cushman, 1928
Cymbaloporetta cf. *C. bradyi* Cushman, 1949
Figure 16

1949 *Cymbalopora poeyi* (d'Orbigny) var. *bradyi* Cushman: 25, pl. 10, fig. 2; pl. 14, fig.2.

2012 *Cymbaloporetta bradyi* Cushman; Debenay, 2012, 236, 316 (with synonyms)

Description. Test convex on spiral side, trochospiral, peripheral margin rounded, chambers become bigger as added, first trochospirally arranged later added in an annular arrangement, irregularly globular on the spiral side. Wall coarsely perforated on the spiral side except on earliest chamber. Sutures depressed on both sides; curved on spiral side.

Genus *Agglutinella* El-Nakhal, 1983
Agglutinella soriformis El-Nakhal, 1983
Figure 17a–c

1983 *Agglutinella soriformis* El-Nakhal: 130, pI. 1, figs. 7–9, pl. 2, figs 16–18.

1993 *Agglutinella soriformis* El-Nakhal; Hottinger et al., pl. 30, figs 7–10, pl. 31, figs. 1–4.

Description: Test broadly subelliptical in lateral view, polygonal in end view, laterally slightly compressed. Chambers U-shaped in section, initially arranged in distinct quadriloculine and later in a triloculine manner. Aboral end of chamber strongly overlaps preceding chamber. Aperture terminal, broadly drop-shaped, bordered by peristomal lip and provided with a spur-shaped bifid tooth with a long base. Wall porcelaneous with a coarsely agglutinated outer layer.

Genus *Adelosina* d'Orbigny 1826
Adelosina carinatastriata Wiesner, 1923
Figure 17d–f

1923 *Adelosina milletti* Wiesner var. *carinata-striata* Wiesner: 76–77, pl. 14, figs 190, 191.

2005 *Adelosina carinatastriata* Wiesner Debenay et al., 2005, pl. 1, fig. 15.

Description: Test quinqueloculine, oval in outline, numerous costae run obliquely along the chambers and unite peripherally. The aperture is terminal, at the end of a short neck, bordered by a small peristomal rim, with a small bifid tooth.

Genus *Pseudotriloculina* Cherif, 1970
Pseudotriloculina sp.
Figure 17g–i

1993 *Pseudotriloculina* sp. B. Hottinger et al., 1993, pl. 49, figs. 1–7.

Description: Test porcelaneous, elongate, narrow elliptical in lateral view. Chambers arranged in a quadriloculine manner, sutures rather indistinct. Aperture terminal, rounded, at the end of a distally narrowing extension of the chamber, producing a short, stout neck lacking a distinct lip and provided with a broadly bifid, spoon-like tooth with a very short base.

Genus *Spiroloculina* d'Orbigny, 1826
Spiroloculina indica Cushman & Todd, 1944
Figure 17j–l

1944 *Spiroloculina indica* Cushman & Todd: 71, pI. 9, fig. 32.

1993 *Spiroloculina indica* Cushman & Todd; Hottinger et al., 1993, pl. 26, figs 10–14.

Description: Test porcelaneous, biloculine, evolute, fusiform in lateral view, strongly biconcave. The aperture is circular, situated at the end of a stout neck, surrounded by a peristomal lip and provided with two teeth, an anvil-shaped bifid one at the inner margin and a primitive bifid tooth at the outer margin.

3.4 Discussion

The percentages of abnormalities (1.94%) recorded for all the picked specimens in this study is higher than the 1% value, suggested as the typical background value representing a natural undisturbed population in previous studies (Yanko et al., 1998; Stouff et al., 1999). During the sample preparation of the cross section of *Agglutinella soriformis* (Figure 18e–f), the internal content appeared pinkish, suggesting that the foraminifera was recently alive. There are no indications of preferential host selection, the epibiont seems to attach onto any available basibiont, including *Agglutinella soriformis*, *Pseudotriloculina* sp., *Adelosina carinatastriata* and *Spiroloculina indica.* Constriction of the test and subsequent growth of the basibiont's chambers at the point of attachment of the epibiont may suggest an early attachment in their ontogeny. Studies have documented symbiotic feeding relationships (i.e., predation, symbiosis, and commensalism) between foraminifera and other organisms (Hallock and Talge, 1994; Nielsen et al., 2002). However, little is known about intraspecific biotic factors such as parasitism affecting them. This study therefore underlines the importance of biotic factors (such as parasitism) in foraminiferal ecology, which has been previously largely underestimated (Murray, 2006). In the Arabian Gulf region, this study may have a direct implication on the determination of foraminiferal abnormality percentages, which have been previously correlated to levels of pollution in marine environments (Yanko et al., 1998; Frontalini et al., 2009).

3.5 Conclusions

The finding of morphological test abnormalities most likely caused by an epibiont in an unpolluted environment has important implications for the use of the morphological abnormalities for pollution biomonitoring. A possible parasite-host (parasitism) relationship of the epibiont cannot be ruled out. Possible evidence of a parasitic mode of life is inferred from the modification of the host chambers. Cross sections of *Adelosina carinatastriata* and *Agglutinella soriformis* show some modifications of host chambers at the point of attachment to accommodate the epibiont. Future studies are needed to separate test abnormalities caused by epibionts from those attributable to different types of pollution and to better constrain the possible parasitic *vs*. epibiont- relationship of *Cymbaloporetta* sp. Due to the sample size considered in this study, there is a need to conducted a systemtic study of the area based on additional samples.

CHAPTER 4

Pseudonubeculina arabica n. gen. n. sp. a new Holocene benthic foraminifera from the Arabian Gulf

Abduljamiu O. Amao and Michael A. Kaminski

Published in Micropaleontology

SUMMARY–This paper describes an enigmatic new agglutinated benthic foraminiferal genus and species that shares some morphological features with the *Reophax*, *Hormosina* and *Nubeculina* groups. *Pseudonubeculina arabica* n. gen. n. sp. is characterized by its uniserial chamber arrangement, coarsely agglutinated bilamellar test wall with white high-Mg calcite cement, and a terminal slit-like aperture formed by the flat sides of two or more large agglutinated grains. The new genus cannot be placed within any of the previously described families of the Miliolida. The current classification of the Miliolida does not accommodate a genus with a wholly uniserial chamber arrangement. This species can easily be distinguished by its prominent terminal slit-like aperture, formed using the flat sides of two or more large agglutinated grains, lined by an imperforate rim of secreted calcite. The species has a restricted area and depth distribution in the Arabian Gulf.

4.1 Introduction

The Arabian Gulf contains a diverse fauna of benthic foraminifera, which is largely undocumented. In recent studies of modern Gulf foraminiferal faunas, many species are reported in open nomenclature or are only tentatively identified (Parker and Gischler, 2015; Amao et al., 2016b). Much more taxonomical effort needs to be invested in the Arabian Gulf faunas before we can estimate their true biodiversity. The taxonomy of the hormosinid group in particular is in need of revision; many dissimilar foraminifera have been erroneously placed in this group, including several genera that possess calcareous cement. This confusion stems from the morphological similarities based on chamber arrangement and overall test shape, irrespective of wall composition. In this study we describe a new genus and species of foraminifera from the Arabian Gulf that has morphological features in common with the *Reophax*, *Hormosina* and *Nubeculina* groups.

4.2 Methodology

4.2.1 Sample Location

Samples for this study were collected as part of an extended study of the distribution of benthic foraminifera along the Iranian coast (Figure 19) by a team from Ferdowsi University of Mashhad and Geological Survey of Iran. Samples were collected from each station using a van Veen grab (0.1 m^2 area) onboard a research vessel. Sediment samples collected for the benthic study were sieved onboard using a 63 µm mesh and the residual sediments containing foraminifera were stored in 100 ml jars and transferred to the Environment and Water Laboratory at the Research Institute, King Fahd University of Petroleum & Minerals for drying and benthic foraminiferal picking. The dried sample was sieved through a 125 µm mesh sieve, separated into two aliquots with approximately 300 specimens using a microsplitter to ensure statistically representative counts. Selected specimens were imaged using scanning electron microscopy (JSM-5900LV SEM) and light microscopy (Nikon-1500 photomicroscope with a Sony digital camera) at the Earth Sciences Department, KFUPM.

A modified resin embedding technique (Golubic et al., 1970), which is based on two component epoxy resins allowing faster setting of the resin and limiting the penetration into the foraminiferal test, was used. The resin casts were further ground on a smooth glass plate with abrasive powder (#1000). After achieving the appropriate depth, resin casts were placed in an ultrasonic water bath for 30 seconds to remove abrasive powder residue and then dried under an incandescent lamp. The resin cast provides support for handling the specimen, enables desirable precise smoothness to be achieved and allows the study of the internal components of the foraminifera. The faunal reference slides are currently housed in the author's collection at KFUPM. The type specimens of the new species are permanently archived in the European Micropaleontological Reference Center at Micropress Europe in Kraków (Poland). Energy Dispersive X-ray (EDX) analysis on points within the internal lining of the foraminifera was carried out at Baker Hughes Dhahran Technology Research Facility (Dhahran, Saudi Arabia) using Quantitative Evaluation of Minerals by Scanning Electron Microscopy (QEMSCAN) and its inbuilt EDX probes. The purpose of the EDX analysis is to verify the minerology of the test wall.

4.3 Systematic Descriptions

Family. Uncertain.
Genus *Pseudonubeculina* n. gen.
Type species. *Pseudonubeculina arabica* n. gen. n. sp.

Description. Test wholly uniserial, with few, strongly overlapping chambers, externally resembling the genus *Hormosina*. Wall comprised of a thin imperforate calcareous inner layer and a coarsely agglutinated outer layer with abundant white calcareous cement composed of high magnesium calcite. Aperture terminal, a slit formed by the flat sides large agglutinated grains placed around the aperture.

Remarks. Differs from *Hormosina* in possessing calcareous cement and a slit-like aperture, and from *Nubeculina* and *Hormosina* in possessing a completely uniserial chamber arrangement and strongly overlapping chambers. *Hormosina* also possesses a distinct apertural neck, while *Acostata* which is a recent uniserial taxon with a slit-like aperture, has walls with an organic cement. *Cribratinoides,* which is uniserial, possesses a slit-like aperture and calcareous cement, however, the chambers are many and closely appressed. *Glaucoammina* Seiglie & Bermúdez, possesses calcareous cement with canaliculae, and is regarded to be a clavulinid that has lost its triserial part (Loeblich and Tappan, 1987)

Pseudonubeculina arabica n. gen. n. sp.
Figure 20 a–c; Figure 21(1–3), Figure 22 a–b

Description. Test is uniserial elongate, composed of 2 to 4 regular, strongly overlapping chambers with distinct sutures. Chambers are rounded in cross-section and nearly uniform in size throughout the length of the test. Chamber interior simple, chamber lumen are separated by a foramen, which is a constriction of the ends of chambers created by the flat surfaces of agglutinated grains. Wall is comprised of two layers, a thin imperforate inner calcareous layer and a much thicker coarsely agglutinated outer layer, a single grain thick, consisting of rounded terrigenous sand grains and occasional tests of other foraminifera, held by a porcelaneous cement (high-Mg calcite). The dimensions of grains comprising the chamber wall are rather uniform, but noticeably larger grains are used to construct the aperture. Aperture is a simple terminal slit, without a tooth, usually constructed with the flat ends of two or more broad agglutinated grains.

Type Locality. Lat. 26.46667 N, Long. 54.98333 E, water depth 31 m. The type specimens (Table 1) were recovered from four samples collected from a narrow depth range (20–31 m) in the Arabian Gulf.

Type Level. Recent

Type Specimens. Holotype and paratypes are deposited in the collections of the European Micropaleontological Reference Centre, Micropress Europe, in Kraków, Poland in Cabinet 6, drawer 6. (#6/6c-1–5).

Remarks. The species resembles those assigned to *Nubeculina* by Parker (2009, figs. 104 and 105) and Loeblich and Tappan (1994, plate 59, figs. 4–10) with its distinct coarsely agglutinated wall, milky white cement color and the almost uniform uniserially arranged chambers. However, this species can easily be distinguished by its prominent terminal slit-like aperture, about 100 µm in length, formed using the flat sides of two or more large agglutinated grains, lined by an imperforate rim of secreted calcite (Figure 20-2a). It is not clear from the axial section of Parker (2009, page 147, figs. 105 f–h) whether the displayed wall texture is original or acquired from the media used in impregnating the specimen before it was sectioned.

Our new species shows some variation in size, depending on the type and grain size of the agglutinated material. Analyses of the agglutinated grains used to construct the test confirm that most are quartz, although occasionally small tests of calcareous benthic foraminifera are also incorporated into the wall. The agglutinated layer is a single grain thick (Figure 21). The cement between the grains is milky white high-Mg calcite (Table 2) and is imperforate. No pseudopores or canaliculi have been observed.

The chambers externally appear to be globular and of nearly uniform dimensions, circular in cross-section, but sectioned specimens reveal that the chamber lumen has a pyriform shape, tapering toward the aperture. The chambers increase in size very slowly or not at all. The foramen between chambers is about 25 µm wide, and clearly lined with a calcite layer a few microns thick. The organism selects and positions the agglutinated grains in such a manner to create a foramen of remarkably constant diameter.

The species externally resembles *Reophax bradyi* Bronnimann and Whittaker, 1980, but differs in possessing a bilamellar wall with white calcareous cement and a slit-like aperture. The species from Ningaloo Reef identified as *Nubeculina advena* Cushman by Parker (2009) also possesses globular, overlapping, uniform chambers but clearly differs in its apertural characteristics and in possessing a coiled early stage, which is reflected in the arcuate shape of the test. The species has restricted area and depth distribution in the Arabian Gulf. Out of a total of 33 sampling stations studied from the Iranian sector of the Arabian Gulf, only 4 with a depth range of 20–31 m contained the new species (Figure 19).

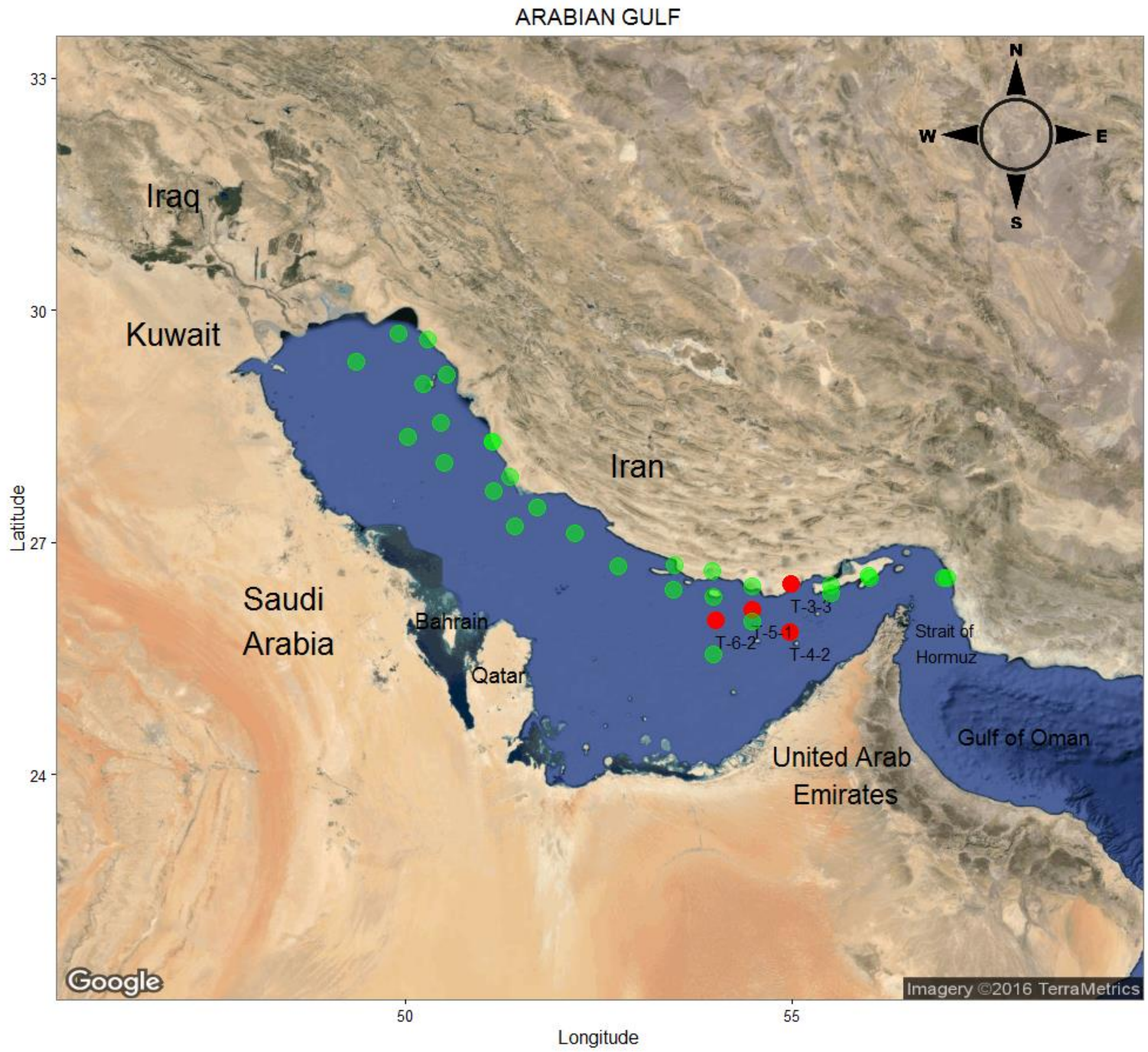

Figure 6. Location map with red points indicating samples containing the new species

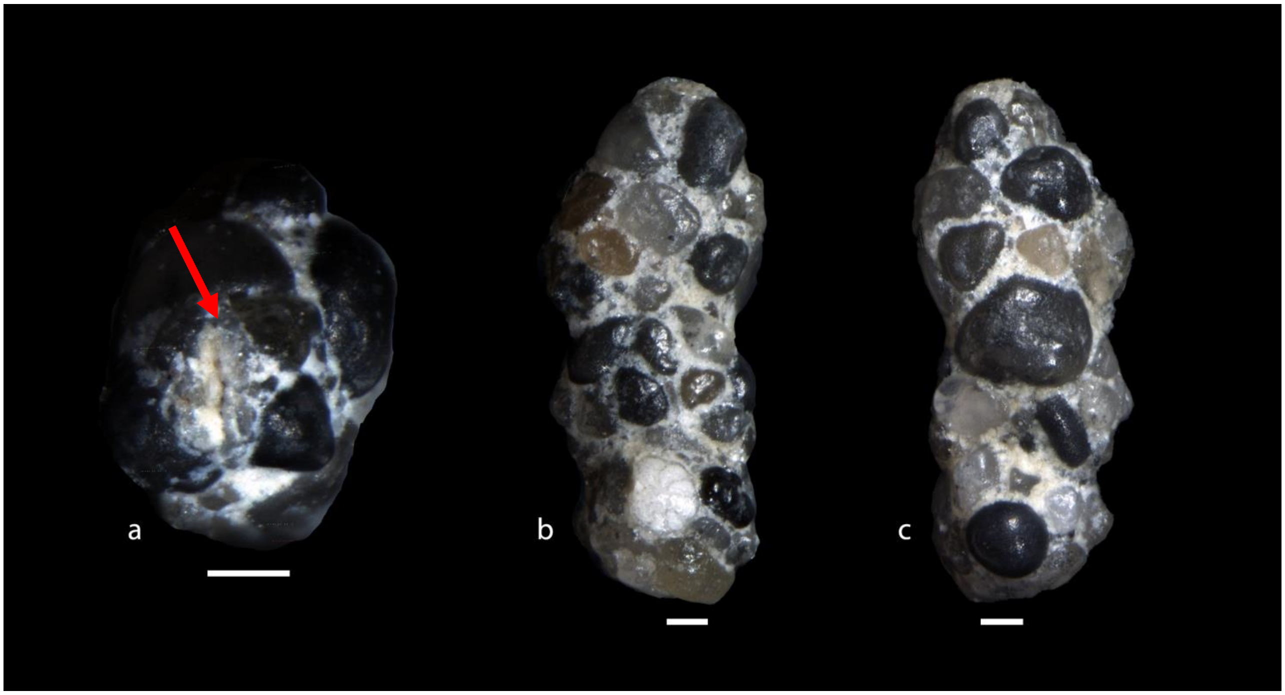

Figure 7. Holotype (sample T5-1) specimen showing the coarsely agglutinated nature of the surface texture, light microscope image, red arrow indicating the aperture. Scale = 100 µm. (#6/6c.1)

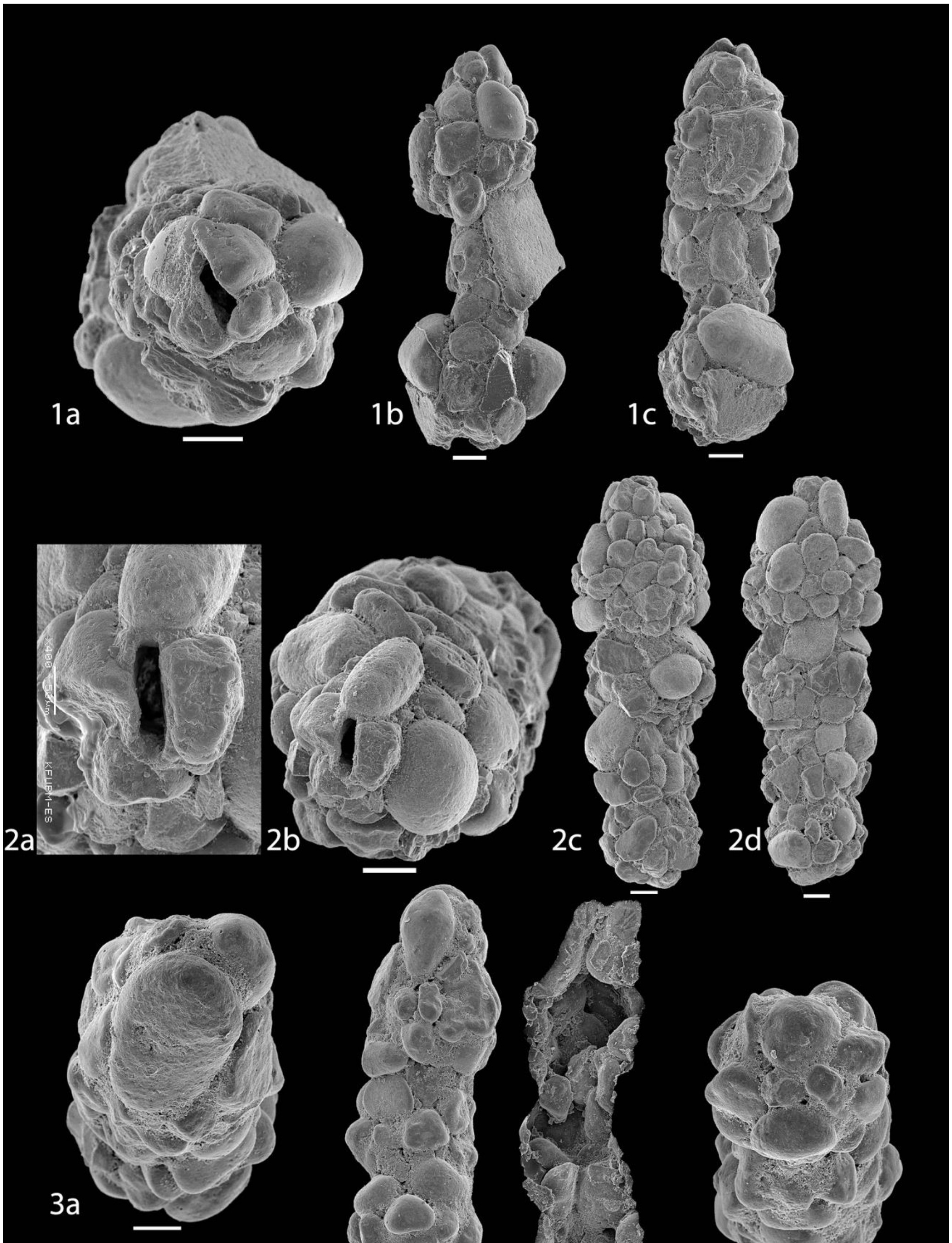

Figure 8. All specimens are paratypes, 1a-c. Sample T6-2, 1a. Apertural view, 2b, c. Lateral view; 2. Sample T6-2, 2a, b. apertural views, 2c, d. lateral views. 3a-d. sample T4-2. 3a. Apertural view, 3b. Lateral view 3c. longitudinal section, showing the inner walls of the chambers 3d. a view of the posterior end of the foraminifera with a prominent rounded grain. Scale bars = 100 µm. (#6/6c.1-4)

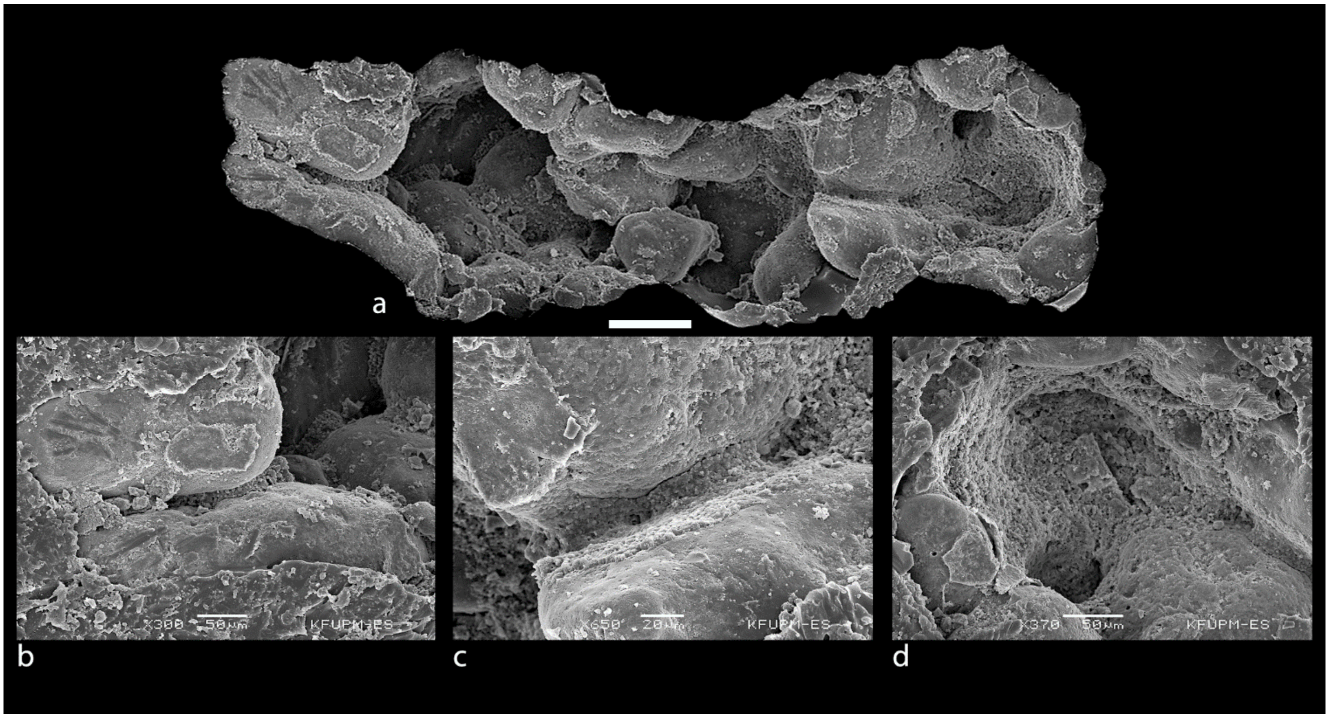

Figure 9. Longitudinal section of a paratype from sample T4-2, showing the uniserial nature of chamber arrangement and details of the aperture (b), the foramin between chambers(c) and the first chamber (d). Scale = 100 µm unless otherwise indicated. (#6/6c.6)

4.4 Discussion

The systematic position of the new genus *Pseudonubeculina* remains uncertain. Based upon its wholly uniserial chamber arrangement and simple aperture, the genus would traditionally be placed in the *Hormosinina*, which possesses calcareous cement and a slit-like aperture. However, *Hormosina* possesses a distinct apertural neck and strongly overlapping chambers. The Jurassic uniserial genus *Posadia* Guisberti & Coccioni is described as having calcareous cement while *Acostata*, which is a recent uniserial taxon with a slit-like aperture, has walls with an organic cement. *Cribratinoides*, which is uniserial, possesses a slit-like aperture and calcareous cement, however, the chambers are many and closely appressed. Another genus, *Glaucoammina* Seiglie & Bermúdez, possesses calcareous cement with canaliculae, and is regarded to be a clavulinid that has lost its triserial part (Loeblich and Tappan, 1987). These genera have been placed within the Hormosinina in spite of their calcareous cement composion (Kaminski, 2014).

Our new genus *Pseudonubeculina* undoubtedly has miliolid affinities owing to the structure and composition of the test wall, and may, in a manner similar to *Glaucoammina*, simply be a nubeculinid that has lost its initial planispiral coil and has become wholly uniserial. However, the current classification of the Miliolida does not accommodate a genus with a wholly uniserial chamber arrangement.

Table 1. Sample stations containing the new species

Station	Latitude	Longitude	Depth(m)	Relative Abundance (%)
T-3-3	26.46667 N	54.98333 E	31	0.8
T-4-2	25.83333 N	54.96666 E	22	1.5
T-5-1	26.13333 N	54.48333 E	24	2.0
T-6-2	25.99755 N	54.00503 E	20	0.7

Table 2. Summary of Energy dispersive X-ray (EDX) analysis on points within the internal linning of the paratype #6/6c.6 (The paratype was cut open (Figure 22))

Element	Spectrum 2 (Wt %)	Spectrum 2 (Wt %)
C	40.98	31.37
O	34.99	39.21
Mg	4.5	3.15
Si	9.66	5.73
Ca	9.87	20.54

CHAPTER 5

The new foraminiferal species *Pseudotriloculina hottingeri* n. sp. from the Arabian Gulf

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Submitted to Journal of Foraminifera Research

SUMMARY-- This study describes a new species belonging to the miliolid foraminiferal genus *Pseudotriloculina*. The species *Pseudotriloculina hottingeri* n. sp. is here described from several locations sampled in the Arabian Gulf. The species is distinguished by its U-shaped chambers, arranged initially in an indistinct triloculine and later in a pseudotriloculine manner, porcelaneous wall with longitudinal or bifurcating costae ornamentation running along the chambers from the posterior end to the apertural margin. It also has a short, broad, spoon-like bifid tooth within a terminal aperture and a broad collar draped on the last chamber. The species is named for Professor Lukas Hottinger who first described the species from the Gulf of Aqaba, Red Sea. The species has a restricted bathymetric and ecological distribution in the Arabian Gulf. The species has a depth range 0.02–17 m, tolerates salinity of 36–52 ppt and a temperature of 27–30°C. Specimens were found in 20 samples out of 78 sampling stations studied in the entire Arabian Gulf. The species appears to have ecological significance in understanding epibiont-basibiont interactions and can also be used to delineate restricted environments based on its ecological preferences.

5.1 Introduction

Recent documentation of high diversity of foraminifera in the Arabian Gulf supports the notion that the area is largely understudied and the diversity of foraminifera seriously underestimated (Parker and Gischler, 2015; Amao et al., 2016b). Amao et al. (2016b) reported a high species diversity (120 species) from a small shallow lagoon in Bahrain, higher than any number earlier reported for the entire region [e.g., 72 species in the "southern Arabian Gulf biofacies" reported by Cherif et al. (1997)]. These estimates are still far lower compared with the number benthic foraminiferal species (350) identified in the Gulf of Aqaba (an extension of the Red Sea) by Hottinger et al. (1993) and 1000 species in the Mediterranean Sea reported by Frontalini et al. (2015). One of the greatest challenges is a lack of a taxonomic guide that documents the unique assemblage in the area. Therefore, as part of a larger research effort to document the distribution, taxonomy and ecology of foraminifera in the Arabian Gulf, this study describes a new species belonging to the miliolid foraminiferal genus *Pseudotriloculina*. We name the species after Lukas Hottinger, in recognition of his valuable research on modern Foraminifera of the Red Sea area.

The Arabian Gulf provides an excellent environment for the study of biotic and abiotic factors due to notable extremes [e.g., temperature and salinity (Amao et al., 2016b)]. The area is currently undergoing changes and deterioration of benthic communities as a result of rapid urban development and pollution (Sheppard et al., 2010). Salinity and water temperature for the area for the study area has been well documented in previous studies (Clarke and Keij, 1973; John et al., 1990; Joydas et al., 2015; Amao et al., 2016a, 2016b).

5.2 Methodology

Samples for this study were collected from 78 locations within the Arabian Gulf, covering a range of environments including shallow to deep marine areas, and restricted and open environments (Figure 23). The samples also mirror the bathymetry of the Arabian Gulf and the major sedimentary regimes; carbonate-dominated, rimmed platform to the west and a mixed siliciclastic regime to the east. The samples were collected in our previous study of taxonomy and spatial distribution of benthic foraminifera in the Arabian Gulf. Standard handling and processing techniques were applied to the samples. See Amao et al. (2016a, 2016b) for details on sample preparation, preservation, and processing. Selected specimens were imaged by using scanning electron microscopy (SEM-JEOL JSM-5900LV) at the Geosciences Department, King Fahd University of Petroleum & Minerals (KFUPM) in Dhahran, Saudi Arabia. To produce the cross sections, a modified resin embedding technique (Golubic et al., 1970), which is based on two-component epoxy resins allowing faster setting of the resin and limiting the penetration into the foraminiferal test, was used. To achieve the faster setting of the resin, the casts were cured in an oven for 30 minutes at 100^{o}C. The resin casts were ground on a smooth glass with silicon carbide loose grit abrasive powder (grit size #400). After achieving the appropriate depth, resin casts were placed in an ultrasonic water bath for 30 seconds to remove the abrasive powder residue and then dried under an incandescent lamp. The resin cast provides support for handling the specimen and also enables desirable precise smoothness to be achieved during grinding. The type specimens of the new species are permanently archived in the European Micropaleontological Reference Center at Micropress Europe in Kraków (Poland).

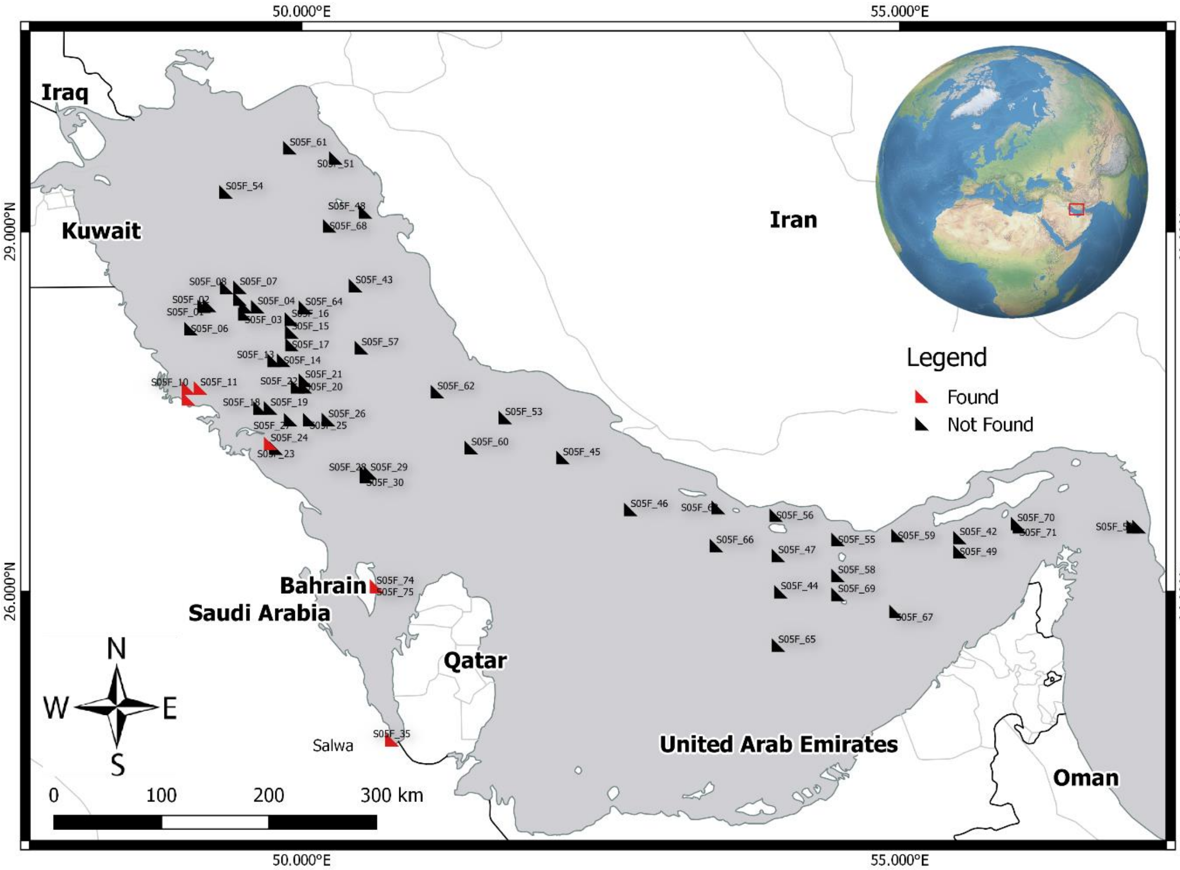

Figure 10. Location of samples used in the study, red right-angle triangles indicate sites where the species was found, while black indicate sites where the species was not found. In Salwa and Bahrain, the sampling sites with *P. hottingeri* represents 5 and 9 stations respectively, which are not visible due to the map scale

Figure 11. Holotype (#7/6d-1) showing longitudinal ornamentation, terminal aperture, and broad bifid tooth. a - apertural view, while b and c are lateral views of the specimen. Scale = 100 µm.

Table 3. Sampling station details and relative abundances of *P. hottingeri* recovered, expressed as percentage of the total assemblage at each station.

Station	Latitude	Longitude	Depth (m)	*Relative abundance (%) of P. hottingeri*
S05F_78	26.0435130	50.6253670	0.40	4.49
S05F_11	27.6979524	49.1536030	9.20	4.20
S05F_10	27.6965762	49.0531496	8.70	4.10
S05F_74	26.0444720	50.6264440	1.00	3.64
S05F_36	24.7632110	50.7533070	0.98	3.30
S05F_33	24.7636080	50.7539650	0.60	2.90
S05F_76	26.0433740	50.6255230	0.02	2.49
S05F_24	27.2344377	49.7410607	17.10	2.40
S05F_12	27.6067703	49.0547400	5.70	2.30
S05F_72	26.0436170	50.6252210	0.02	2.17
S05F_38	24.7630100	50.7529260	1.20	1.80
S05F_34	24.7634670	50.7537410	0.76	1.50
S05F_37	24.7631110	50.7531140	1.09	1.50
S05F_35	24.7633440	50.7535210	0.87	1.30
S05F_39	24.7629100	50.7527280	1.31	1.30
S05F_31	24.7637910	50.7542240	0.40	1.20
S05F_32	24.7636080	50.7539650	0.60	1.20
S05F_41	24.7627080	50.7522750	1.64	0.80
S05F_73	26.0436690	50.6251410	0.40	0.77
S05F_77	26.0434030	50.6254990	0.04	0.60

5.3 Systematic Description

Family HAUERINIDAE Schwager, 1876
Subfamily MILIOLINELLINAE Vella, 1957
Genus *Pseudotriloculina* Cherif, 1970
Type species: *Triloculina laevigata* d'Orbigny, 1828 (O.D.)

Pseudotriloculina hottingeri Amao and Kaminski, 2016
Figure 24, Figure 25, Figure 26

1993 *Pseudotriloculina* sp. B. Hottinger et al., 1993, p. 56, pl. 49, figs. 1–7

2016 *Pseudotriloculina* sp. Amao et al., 2016, p. 177, fig. 3 g–i

Description. Test elongated, oval in lateral view and somewhat compressed. Periphery generally rounded except in deformed specimens. Wall porcelaneous with costate ornamentation running longitudinally or bifurcating along the chambers from the posterior end to the apertural margin. In transverse sections, chambers are oval-U-shaped, arranged initially in an indistinct quadriloculine manner and later in a pseudotriloculine manner. Sutures are indistinct; aperture is terminal, rounded with a short broad spoon like bifid tooth. The prominent aperture rim drapes on the last chamber forming a collar.

Remarks. Paratypes show variation in the size and numbers of costae (9–30). Differences in size among the paratypes may suggest the specimens imaged are at different growth stages. The species resembles those assigned to *Pseudotriloculina* sp. B by Hottinger et al. (1993, page 54, plate 49, figs. 1–7) with its distinct short, broad, spoon-like bifid tooth and numerous, somewhat delicate costae. It also shares some similarities with *Quinqueloculina limbata* d'Orbigny, *Triloculina cohabilis* and *Quinqueloculina tenagos* Parker as discussed by Hottinger et al. (1993). *Quinqueloculina limbata* and *Q. cohabilis* have longer necks, while *Q. tenagos* appears more robust.

Derivation of Name. The new species is named in honor of Professor Lukas Hottinger who earlier described the species from Gulf of Aqaba of the Red Sea.

Type Locality. Eastern Bahrain; Latitude 26.044472 N, Longitude 50.626444 E, foreshore off Askar fishing village (Figure 23), water depth approximately 0.4 m. The type locality and its environmental parameters have been described by Arslan et al. (2016).

Type Level. Recent

Type Specimens. Holotype and paratypes are deposited in the collections of the European Micropalaeontological Reference Centre, Micropress Europe, in Kraków, Poland in Cabinet 7, drawer 6. (#7/6d-1–3).

Ecological Preference. The species has a restricted bathymetric and ecological distribution in the Arabian Gulf. Specimens were only found in 20 samples out of 78 sampling stations studied for the entire Arabian Gulf (Figure 23). Also, living populations were only documented among the 20 samples (Table 3). The species has a depth range of 0.02–17 m, tolerates salinity in the range of 36–52 ppt and temperatures of 27–30°C based on a one sampling event. Details of all sampled locations in the Gulf are provided as supplementary material (Appendix-Table 1).

5.4 Summary and Conclusion

Valid controversy continues concerning the genus *Pseudotriloculina* attributed to Cherif (1970), which was first published in a Ph.D. dissertation (Loeblich and Tappan, 1985). Cherif in his later papers (Cherif, 1973; Cherif et al., 1997; Cherif and Flick, 1974), refers to his 1970 work as a dissertation, and at some point he even refers to it as a photocopy. This seems to suggest that *Pseudotriloculina* was not originally a valid name according to the rules of the International Commission on Zoological Nomenclature (ICZN). However, several notable taxonomic monographs have used and referred to this citation (Loeblich and Tappan, 1987, 1994; Hottinger et al., 1993; Debenay, 2012). For the purpose of convenience, this study considers *Pseudotriloculina* Cherif, 1970 to be a valid genus name.

Pseudotriloculina hottingeri n. sp. appears to have ecological significance in understanding epibiont-basibiont interactions. Amao et al., (2016a) documented test abnormalities as a result of *Cymbaloporetta* sp. (epibiont) attaching to the test of *Agglutinella soriformis*, *Adelosina carinatastriata*, *Spiroloculina indica* and *Pseudotriloculina* sp. (*Pseudotriloculina hottingeri*). The interaction may have implications for the ontogeny and development of abnormalities in the bassibiont foraminifera. Locally, this may also affect how abnormality indexes for pollution biomonitoring are interpreted due to the significant number of the biological interactions documented. We suggest that *P. hottingeri* can be used to delineate restricted environments based on its ecological preferences, i.e., shallow hypersaline environments in the Arabian Gulf, and not only in the Red Sea. It may also be useful in combination with other benthic foraminifera for depth proxies.

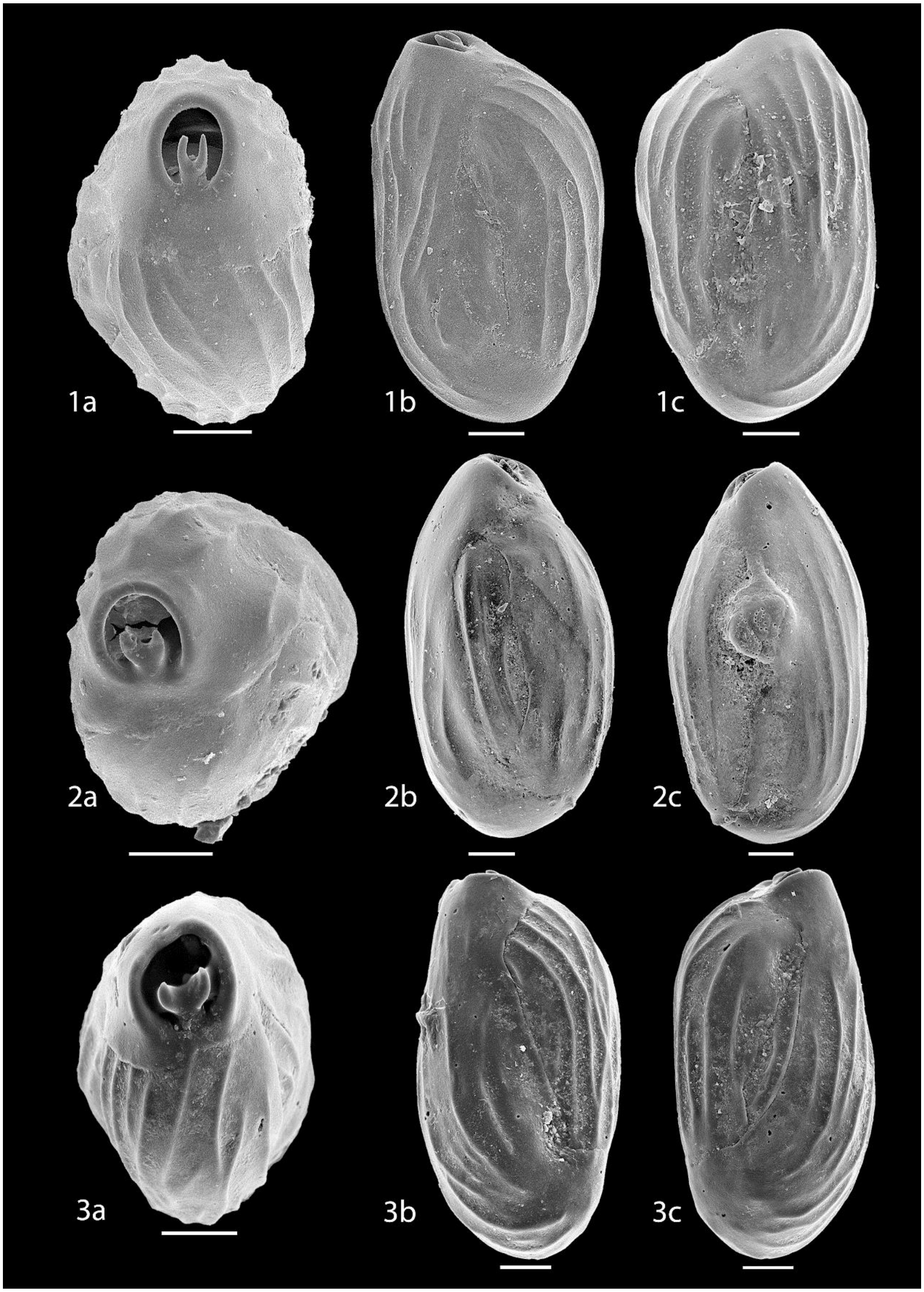

Figure 12. All specimens are paratypes, Paratype 1. (1a-c). 1a. Apertural view, 1b, c. Lateral views; Paratype 2. (2a-c). 2a apertural views, 2b, c. lateral views. Paratype 3. (3a-d). 3a. Apertural view, 3b, c. Lateral view. In 2c, the knob is the attachment of *Cymbaloporetta* sp. (epibiont). *S*cale bars = 100 µm. (#7/6d-1-3)

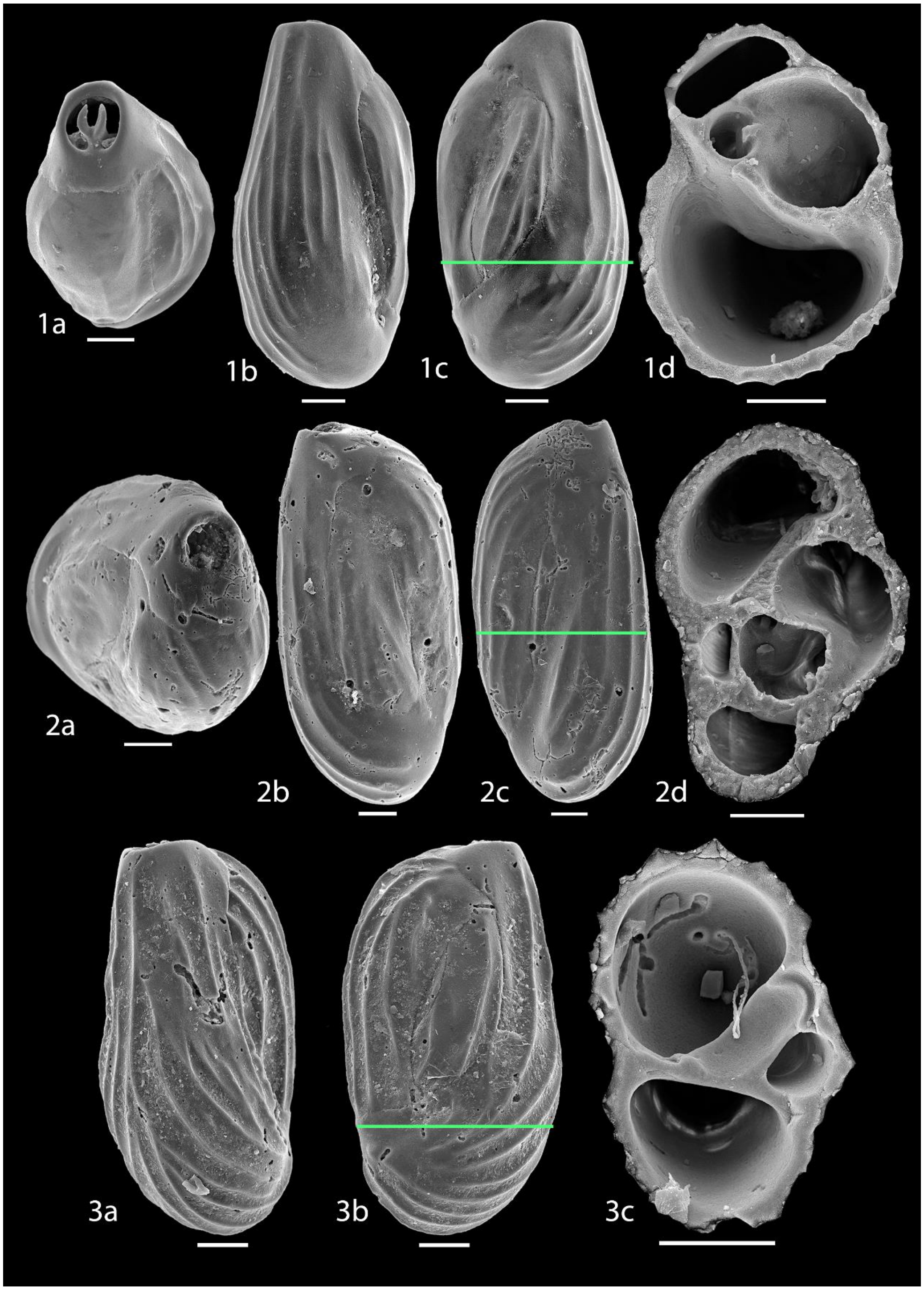

Figure 13. All specimens are paratypes, Paratype 4 (1a-d). 1a. Apertural view, 1b, c. Lateral views, 1d. Transverse section showing chamber arrangement; Paratype 5. (2a-d). 2a apertural views, 2b, c. lateral views. 2d. Transverse section showing chamber arrangement; Paratype 6. (3a-d). 3a and b. Lateral views 3c. Transverse section showing chamber arrangement. Scale bars = 100 µm. (#7/6d-4-6). The green line drawn across 1c, 2c and 3b indicate the relative position of the transverse sections.

CHAPTER 6

Status of Benthic Foraminifera in the Hypersaline Salwa Bay (Saudi Arabia)

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SUMMARY-- The Arabian Gulf is considered a naturally stressed environment due to extremes of salinity and summer temperatures and the Salwa Bay area is often referred to as the most hypersaline extension of the Gulf. The purpose of this study is to document the foraminiferal diversity, abundance and deformity rates in the hypersaline Salwa Bay, near the Saudi Arabia–Qatar Border. The times averaged benthic foraminiferal species are dominated by porcelaneous taxa (85 %), followed by hyaline (15%). The ten most abundant species are: *Peneroplis pertusus* (24.0%), *P. planatus* (15.4%), *Coscinospira hemprichii* (9.1%), *Ammonia convexa* (6.6%), *Quinqueloculina* sp. 1 (3.9%), *Elphidium advenum* (3.9%), *E. craticulatum* (3.5%), *E. gerthi* (3.0%), *A. tepida* (3.0%), *Elphidium* sp. 1 (3.0%). *Peneroplis pertusus*, *P. planatus* and *C. hemprichii* account for ~48% of the total assemblage. A quarter of the specimens counted were stained (Rose Bengal stained), and approximately 43% of the most common taxa (i.e., *Peneroplis*, *Coscinospira*, *Miliolinella*, *Ammonia*, *Elphidium*, *Triloculina*, *Quinqueloculina* and *Lachlanella)* are mildly to severe deformed. Forms of deformities include fusion of two adults or double tests, protuberances on the spiral side, abnormal chamber arrangement, abnormal shape of the proloculus, and modification of the coiling plane in several chambers. *Peneroplis* (58.4%) and *Coscinospira* (17.1%) account for 75.5% of all the observed test deformities. We speculate that the combination of high temperatures, high salinities and the ecology of the taxa encountered are responsible for the high rates of deformities, high abundances, and comparatively low diversity in the Salwa Bay. We conclude that the percentage of abnormalities is not a useful environmental proxy for pollution in a naturally stressed environment such as Salwa Bay due to the high background deformity rates documented in this study.

6.1 Introduction

Due to continuous natural and human-induced changes in coastal environments, living foraminifera are increasingly used to monitor, characterize and generate baseline understanding of marine environments. Human-induced changes in water quality can result from discharge of wastes from industrial and domestic sources (Sheppard et al., 2010; Jones, 2013), often causing eutrophication and anoxia. Responses of benthic foraminifera to heavy metal pollution (Yanko et al., 1994, 1998; Tylmann et al., 2007; Coccioni et al., 2009; Frontalini et al., 2009), nutrient input (Nikulina et al., 2008; Frontalini and Coccioni, 2011; Martins et al., 2015) and natural stress (Murray, 1970; Clarke and Keij, 1973; Geslin et al., 1998; Debenay et al., 2001; Prazeres et al., 2016; Prazeres and Pandolfi, 2016; Schmidt et al., 2016) are well documented in the literature.

Benthic foraminifera have proven useful in the understanding of impacts of elevated temperature (Prazeres et al., 2016; Prazeres and Pandolfi, 2016; Schmidt et al., 2016; Titelboim et al., 2016) and ocean acidification (Fabry et al., 2008; Bernhard et al., 2009; Khanna et al., 2013; Knorr et al., 2015; Prazeres et al., 2015). Both of these changes are a consequence of increasing atmospheric carbon dioxide concentration. Foraminifera respond to environmental changes by either displaying community-level structural and compositional changes, diversity decrease, an increase in numbers (opportunistic species), or an increased frequency of test abnormalities and mass mortality (Jones, 2013). Typical percentages of background abnormalities have been determined for “normal environments”, that is, natural undisturbed populations (Yanko et al., 1998; Stouff et al., 1999). In laboratory culture experiments, *Ammonia* sp. juveniles exhibited high abnormality rates (50%) when the salinity was very high (Stouff et al., 1999). Higher rates (>50‰) have been reported for peneroplids in hypersaline pools and embayments in the Arabian Gulf (Murray, 1970; Clarke and Keij, 1973).

The Arabian Gulf offers a natural environmental setting for the study of the interplay between anthropogenically-induced nutrient gradients, natural stress (salinity and temperature) and the adaptive responses of foraminifera. The Arabian Gulf is the most extensive stretch of hypersaline shelf on Earth and is unique for its endemic flora and fauna that have adapted to extremes of salinity and temperature (Murray, 1991; Naser, 2011). The current thermal regime in the Arabian Gulf has been cited as a model for the tropical ocean in 2090–2099 (Solomon et al., 2007; Riegl and Purkis, 2012). The aim of this study is therefore to document benthic foraminiferal diversity and quantify the test deformities of different taxa in the hypersaline Salwa Bay area, so as to understand the impacts (if any) of natural processes on the fauna composition.

6.1.1 Geography and Geological Setting of the region

The Arabian Gulf (Gulf) is a late Pliocene to Pleistocene shallow tectonic depression produced by the Zagros Orogeny, a tectonic event that occurred due to the collision and compression between Arabia and Asia plates. It is a marginal sea extension of the Indian Ocean, and it covers an area of approximately 22,600 km^2 (Kassler, 1973; Seibold et al., 1973). It is elongated along its axis trending NW–SE; measures 1000 km in length, 300 km at its widest point, and 60 km where it is constricted by the Strait of Hormuz and opens into the Indian Ocean (Purser, 1973; Murray, 1991). Its morphology is influenced by the interaction between the Arabian platform and Zagros folds, that is, a relatively stable Arabian foreland flanking the Pre-Cambrian Arabian shield and subsiding below the unstable Zagros fold belt area (Kassler, 1973; Purser and Seibold, 1973). The Gulf is often subdivided into two sedimentary realms based on predominant sediment types; autochthonous carbonate with siliciclastic admixture dominating the southern Arabian realm and the northern fluvial Iranian realm (Riegl et al., 2010).

The topography of the Gulf's sea floor, which predominantly has very gentle gradients and several bathymetric highs (especially in the south), also reflects the interaction between the Arabian Peninsula and Zagros Mountains (Purser, 1973). Coupled with salt diapirism, the Gulf has >20 islands and several bathymetric highs (Kassler, 1973). The deeply submerged highs are important areas for foraminiferal sand accumulation, particularly towards the basin axis (Riegl and Purkis, 2012). Compared to the rocky, mountainous terrain of the Iranian coast, the Arabian shelf is gentler, wider and largely produced by salt diapirism or erosional relicts of the Quaternary (Kassler, 1973). The presence of the Qatar Peninsula, however, modifies the rather uniform Arabian coastline by changing the pattern of sedimentation and current movement in the southeastern sectors of the Gulf (Riegl and Purkis, 2012). The aforementioned shoreline is also characterized by sabkhas (evaporitic flats), lagoons, embayments, supratidal areas, and extensive storm beaches in more exposed settings (Kassler, 1973; Purser and Evans, 1973; Purser and Seibold, 1973).

Salwa Bay area, which forms a landlocked cul-de-sac between Saudi Arabia and Qatar, is the most saline extension of the Arabian Gulf, with high summer sea-surface temperature and high evaporation rates. Salinity and temperature show steep seasonal differences. Salinity of 55‰ has been recorded at the entrance, increasing to 77‰ in the southern edge of the bay (Basson et al., 1977). The hypersalinity has been attributed to coral reef barriers at the entrance to the area, the shallow nature of the basin (depth), higher residency time of water, and slow flushing rates (Hitmi and Hitmi, 2000; Joydas et al., 2015). Surface water temperatures range from 28–40°C in the summer and 17–25°C in the winter. The nearshore areas of the bay are characterized by extensive hard, rocky bottoms with irregular patches of sand hosting abundant foraminifera (Clarke and Keij, 1973). The rocky bottoms are partly formed as products of Holocene diagenetic processes and partly outcropping pre-Holocene rocks (Shinn, 1969; Clarke and Keij, 1973). Tidal ranges attenuate towards the Salwa Bay interior; from as much as 1.2 m near the bay entrance north of Bahrain, to 0.5 m at the southernmost part of the bay (Sheppard et al., 1992). Floral and faunal diversities have also been reported to decline towards the bay interior, mirroring the salinity gradient (Clarke and Keij, 1973; Riera et al., 2011).

6.1.2 Previous Foraminiferal Studies in the Gulf

There is only one known record of foraminiferal study in the Salwa Bay area, was carried out at a site close to its entrance (Figure 27–green square) by Clarke and Keij (1973). They noted that the foraminiferal assemblages consisted almost entirely of *Peneroplis*. However, the authors also noted in their methodology that their scope of work was not focused on the detailed taxonomy of foraminifera and that they selectively considered the large benthic foraminifera. Other studies on the biogeographical, taxonomic, and ecological studies of foraminifera in the Gulf are localized and asymmetrical. Among the studies, the southwestern (Murray, 1965a, 1965b, 1966a, 1966b, 1966c, 1970; Ahmed, 1991; Basson and Murray, 1995; Hitmi and Hitmi, 2000; Parker and Gischler, 2015; Amao et al., 2016) and northern (Al-Zamel and Cherif, 1998; Al-Zamel et al., 2009, 1996) sectors of the Gulf have received more attention. The eastern part, which stretches along the entire coast of Iran, is poorly known (Haake, 1970; Lutze, 1974d; Haake, 1975). Cherif et al. (1997) reported only 94 benthic foraminiferal species covering a wide range of environments for the entire Gulf.

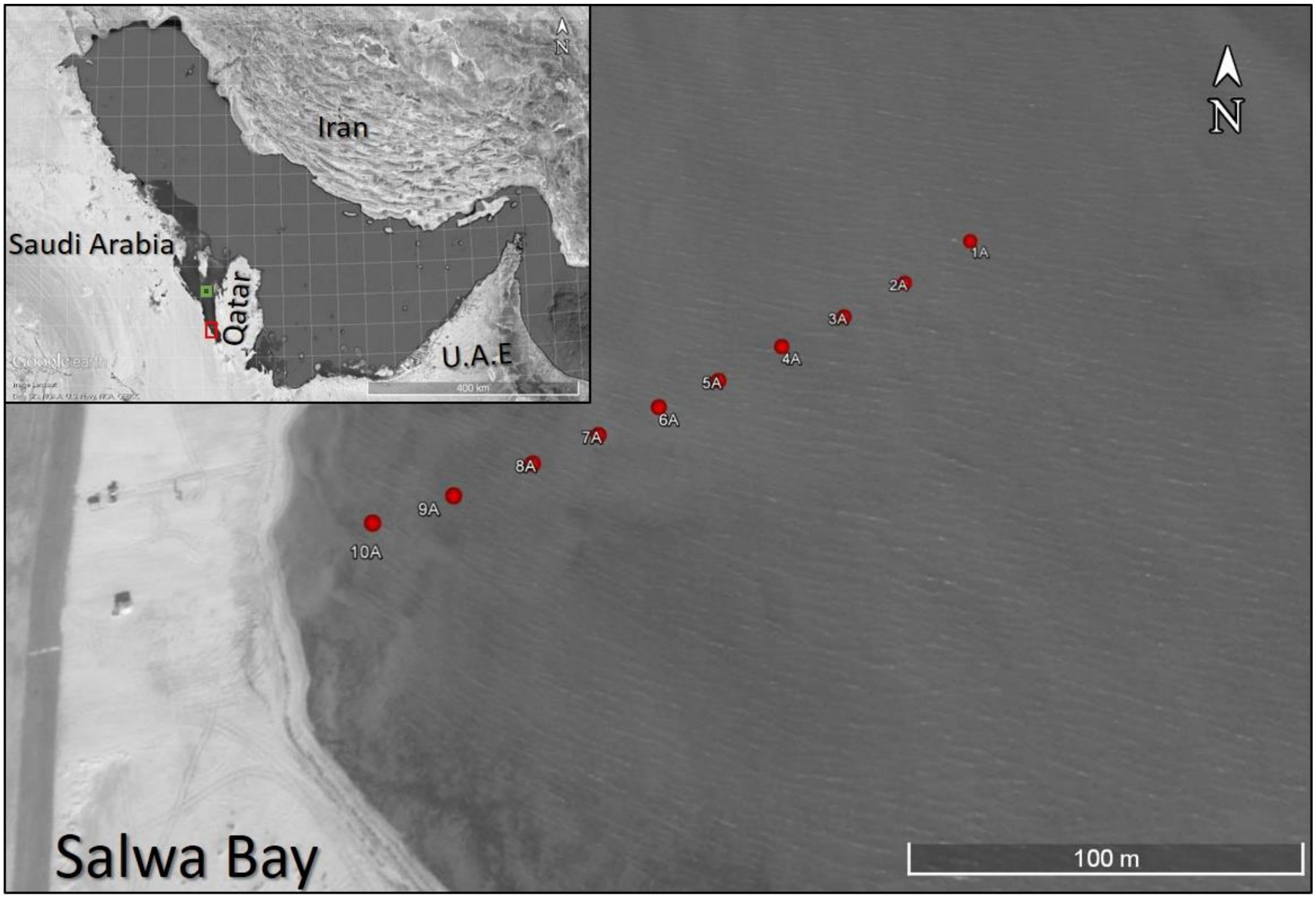

Figure 14. Detail of the sampling transects showing the ten sampled sites (red dots). Inset satellite image showing the regional extent of the Arabian Gulf. The red rectangle (inset map) is the zoomed out area while the green rectangle is the location of the only known previous study of foraminifera in Salwa Bay area by Clarke and Keij (1973)

6.2 Methodology

6.2.1 Sampling

Samples were collected from the top 2 cm sediment surface layer at each station along a 200 m transect using a large plastic syringe. The samples were preserved in a solution of ethanol (70%) and Rose Bengal to enable the identification of specimens that were alive when collected. In the laboratory, a standard volume of sediment (20 g) from each station was subsampled, wet-sieved through a 63-µm mesh and dried in an oven. The dried sample residue was split into aliquots to generate subsamples with approximately 300 benthic foraminiferal tests. The dominant and deformed specimens were illustrated using scanning electron microscopy (SEM) (JEOL JSM-5900LV) at the Geosciences Department, King Fahd University of Petroleum & Minerals (KFUPM) in Dhahran, Saudi Arabia.

6.2.2 Environmental factors

Physical, chemical and hydrographical parameters were measured at each sampling station along the transect (Table 4). Hydrographical parameters such as temperature and salinity were determined using a portable thermometer (9842 Taylor® pro waterproof instant read thermometer) and refractometer (ATC RF20-Salt); capable of measuring salinity between 0–100‰ with an accuracy of ±0.1‰. Replicate samples were prepared following US EPA 3645 method and analyzed for their total organic carbon (TOC) concentrations following US EPA 9060A. The analyses of different Total Petroleum Hydrocarbon (TPH) were carried out following the US EPA 8081 method on gas chromatography with flame ionization detector (GC-FID). Sediment samples were prepared following a modified US EPA 3050 method for trace metals sample preparation protocol. Following the US EPA 6010 method, the concentration of selected heavy metals, including As, Cd, Co, Cr, Cu, Hg, Pb, and Zn, were determined using inductively coupled plasma optical emission spectrometry (ICP-OES) at the center for environment and water at the Research Institute, KFUPM. The cations (Na^+, Mg^{2+}, NH_4^+ & Ca^{2+}) and anions (Cl^-,

NO_3^-, F, Br, PO_4^{3-} and SO_4^{2-}) were carried out on water samples using a modified version of US EPA 300.0 and 300.7 methods on Metrohm 850 Professional Ion Chromatography (Magic Net IC) at the Geosciences Department, KFUPM. Samples from Stations 1 and 2 were duplicated in the analyses for quality assurance purposes.

6.2.3 Grain-Size Analysis

The grain-size distribution of each sediment sample was determined using a laser diffraction method. Prior to the analysis, sediment samples were oven dried at 70°C for 24 hours. The laser diffractometer (Microtract s3500) used can only analyze particles <2mm. As such, approximately 20 g of each samples were carefully weighed and sieved over a 2000 µm mesh for use on the laser diffractometer. No re-adjustment of results was necessary to include the coarser fraction (>2 mm) because none of the samples had significant material >2 mm in the sieve residue. The Microtrac s3500 particle size analyzer (780 nm wavelength laser beam) was operated using standard operating procedure of 15 s measurement time and 2500 rpm pump speed. Two measurement cycles were recorded for each sample and an average taken. Results obtained as volume percentages were analyzed using the GRADISTAT software for determination of grain-size distributions and dominant sediment types. The software neatly summarizes data based on three widely used grain-size standards (i.e., Moment, Wentworth, Folk and Ward Methods). Results obtained include mean grain size, sorting, skewness, kurtosis, etc.

6.2.4 Statistical Analyses

Relative abundances of taxa, Species richness (S), Dominance (D), Shannon-Weaver (H), and eveness (e^H/S) indices were calculated using PAST v3.12 (Hammer et al., 2001) for each sampling station and the foraminiferal relative abundances were standardized prior to analysis by expressing count of individual taxa as a percentage total of each station. Data for boxplots were scaled and centered prior to the analysis, data sub-setting were carried out using R (R Core Team, 2016) by the following packages ggplot2 (Wickham, 2009), tidyr (Wickham, 2016), dplyr (Wickham and Francois, 2015).

6.2.5 Taxonomy and systematics

Identification of foraminifera in this study was based on studies by Murray (1970a), Clarke and Keij (1973), Cherif et al. (1997) and Amao et al. (2016b). The faunal reference microslides are currently housed in the author's collection at KFUPM. These will be permanently archived in the European Micropaleontological Reference Center at Micropress Europe in Kraków (Poland). The World Register of Marine Species collections were used to verify the validity of taxonomic names and groups (WoRMS, 2016).

6.3 Results

6.3.1 Environmental characteristic

Physical, hydrological, chemical and environmental factors measured in the water and sediment samples collected during the sampling event are summarized in Table 4. All the sampling sites reflect the shallow nature of the Salwa Bay and the surrounding environment, with a mean depth of 101.9 ± 42.4 cm. Samples were collected on a summer morning, as such the water temperature was relatively low 27.6 ± 0.4°C. Average salinity was 52.6 ± 0.4 ppt. Total dissolved solid (TDS) and total organic carbon (TOC) showed relatively high average values (49.4 ± 0.1 g/l and 675.4 ± 343.6 mg/kg), while the polycyclic aromatic hydrocarbon (PAH) and total petroleum hydrocarbon (TPH) values were low. Most of the heavy metals assessed, including As, Cd, Co, Cr, Cu, Hg, and Pb, showed very low concentrations. For example, [Cu] ranged from below the detection limit to a maximum of 5.1 mg kg^{-1}. Zinc had a mean concentration of 19 ± 40 mg kg^{-1}. The average concentrations for NO_3^-, PO_4^{3-}, Br^-, F^- were also low. On the other hand, concentrations of the anions Cl^-, SO_4^{2-} and cations Na^+, Mg^{2+}, Ca^{2+} were high, reflecting the high salinity. Concentrations of ammonium [NH_4^+] were consistently very low.

6.3.2 Grain-Size Distributions

The mean grain size values (1.1–1.8 ϕ) from sediments from the proximal (10A) to the distal (1A) sites of the sampled transect show all the samples fall within the same textural group, the sand fraction (Appendix 1-1). The skewness of the particle size ranges from -0.2–0.2 ϕ while the kurtosis values fall between 1.0–1.3 ϕ. The sorting values obtained are between 0.7–1.1 ϕ. Unimodal, moderately sorted sediment types are dominant (75%) among all the sampling stations along the studied transect while 90% of the entire samples are characterized as moderately sorted, medium-grained sand.

Table 4. Summary of environmental factors measured at the sampling sites along the transect

Groupings	Parameters	Unit	Min	Max	Mean	SD
Physical Parameters	Depth	cm	40	164	101.9	42.4
	Salinity	ppt	52.2	53.0	52.6	0.4
	Temperature	°C	27.2	28	27.6	0.4
	TDS	g/l	49.3	49.5	49.4	0.1
Anions and Cations	Cl^-	mg/L	-	9619.0	7252.6	2610.6
	$SO4^{2-}$	mg/L	1.1	1210.0	927.1	331.9
	NO^{3-}	mg/L	0.1	1.8	0.9	0.5
	$PO4^{3-}$	mg/L	-	386.4	104.4	178.7
	Br^-	mg/L	-	142.6	125.8	41.8
	F^-	mg/L	-	1.6	1.1	0.5
	Na^+	mg/L	-	6220.2	4648.1	1682.8
	Mg^{2+}	mg/L	-	668.6	504.0	182.5
	Ca^{2+}	mg/L	-	539.6	436.8	151.3
	NH^{4+}	mg/L	-	82.8	45.9	21.2
Heavy Metals (Sediment)	As	mg/kg	1.0	3.1	2.0	0.6
	Cd	mg/kg	< 0.1	< 0.1	< 0.1	-
	Co	mg/kg	0.3	1.3	0.9	0.3
	Cr	mg/kg	0.2	5.1	3.1	1.6
	Cu	mg/kg	< 0.1	< 0.1	< 0.1	-
	Hg	mg/kg	< 0.001	-	-	-
	Pb	mg/kg	0.4	1.6	0.7	0.4
	Zn	mg/kg	0.2	143.1	18.7	39.7
Petroleum Hydrocarbons (Sediment)	TPH ∑C10-C36	mg/kg	< 0.1	1.7	0.7	0.5
	TPH (Total)	mg/kg	< 0.1	28.0	8.8	9.1
	TOC(mg/kg)	mg/kg	245.7	1236	675.4	343.6
	Naphthalene	ng/g	< 0.1	11.0	1.2	3.1
	Methyl- naphthalene	ng/g	< 0.1	28.2	3.7	8.0
	Acenaph- thylene	ng/g	< 0.1	< 0.1	< 0.1	-
	Acenaph- thene	ng/g	< 0.1	< 0.1	< 0.1	-
	Fluorene	ng/g	< 0.1	< 0.1	< 0.1	-
	Phenanthrene	ng/g	< 0.1	1.4	0.3	0.6
	Anthracene	ng/g	< 0.1	< 0.1	< 0.1	-
	Fluoranthene	ng/g	< 0.1	< 0.1	< 0.1	-
	Pyrene	ng/g	< 0.1	< 0.1	< 0.1	-
	Benzo(a)-anthracene	ng/g	< 0.1	< 0.1	< 0.1	-
	Chrysene	ng/g	< 0.1	5.5	1.5	1.5
	Benzo (b)-fluoranthene	ng/g	< 0.1	1.9	0.3	0.6
	Benzo (k)-fluoranthene	ng/g	< 0.1	1.0	0.1	0.3
	Benzo (a)- pyrene	ng/g	< 0.1	2.3	0.3	0.7
	Indeno (1,2,3cd) pyrene	ng/g	< 0.1	1.4	0.1	0.4
	Dibenzo (a, h) anthracene	ng/g	< 0.1	4.3	1.6	1.3
	Benzo (g, h, i) perylene	ng/g	< 0.1	< 0.1	< 0.1	-

6.3.3 Benthic Foraminifera

A total of 40 benthic foraminiferal species and subspecies belonging to nine genera, seven families, five superfamilies and three orders were identified. The to the actual specimens counted are dominated by porcelaneous taxa (85%), followed by hyaline (15%). The agglutinated foraminiferal groups are represented by only two specimens of *Clavulina* sp. found in sample 2C. The ten most abundant species are *Peneroplis pertusus* (24.0%), *P. planatus* (15.4%), *Coscinospira hemprichii* (9.1%), *Ammonia convexa* (6.6%), *Quinqueloculina* sp. 1 (3.9%), *Elphidium advenum* (3.9%), *E. craticulatum* (3.5%), *E. gerthi* (3.0%), *A. tepida* (3.0%), *Elphidium* sp. 1 (3.0%) (Figure 2). *Peneroplis pertusus*, *P. planatus* and *C. hemprichii* account for ~48% (Figures 29, 30) of all the specimens counted and also dominate the living fauna (Figure 29), morphologically deformed (Figure 30) and eroded fragments (Appendix 1-2).

A summary of the relative abundances of all the taxa encountered in this study is presented in Table 5. Some of the specimens were only identified to the genus level due to lack of type material or minor differences between them and the known species in the same geographical area. Selected taxa are illustrated in Figure 31 to show the common types of test deformity encountered among the large benthic foraminifera in the samples and what was considered as morphologically "normal" test in this study. Hierarchical taxonomic groupings of foraminifera are based on WoRMS (2016), the three orders of benthic foraminifera recognized within Salwa Bay are Miliolida, Rotaliida and Textulariida. The order **Miliolida** is represented by two superfamilies (Milioloidea and Soritoidea), three families (Cribrolinoididae, Hauerinidae, and Peneroplidae) and thirteen genera (*Adelosina*, *Agglutinella*, *Lachlanella*, *Miliolinella*, *Pseudotriloculina*, *Quinqueloculina*, *Triloculina*, *Coscinospira* and *Peneroplis*). Two superfamilies (Discorboidea and Rotalioidea), three families (Rosalinidae, Elphidiidae, and Rotaliidae) and three genera (*Rosalina*, *Elphidium* and *Ammonia*) were identified within the Order **Rotaliida**. The order **Textulariida** is represented by one superfamily (Eggerelloidea), one family (Valvulinidae) and one genus (*Clavulina*).

With respect to diversity indices (Appendix 1-3), the Shannon-Weiner index (Shannon H) was highest (2.9) at station 3A while the lowest value (1.6) was recorded at station 10A. Dominance (Dominance_D) was highest (0.3) at station 10A while the lowest (0.1) was recorded at station 5A. The species richness (Taxa_S) was highest at station 3A (31) while the lowest was recorded at station 10A (9). Station 5A had the highest proportion of individuals in the community distributed more equitably among the species (0.67) while station 2A had the lowest. Station 2A had one additional species and a higher dominance compared to station 5A.

6.3.4 Living and Aberrant Tests

A quarter of the specimens recovered in the sediments were living (Rose Bengal stained) at the time the samples were collected (Appendix 14). The following taxa contributed more than 10% to this value: *Peneroplis* (48%), *Coscinospira* (17.1%), *Ammonia* (10.7%) and *Quinqueloculina* (10.4%). The living component varied greatly among the stations, so the values expressed above are relative abundances of each taxon summed across all the stations. Approximately 43% of the most common taxa (i.e., *Peneroplis*, *Coscinospira*, *Miliolinella*, *Ammonia*, *Elphidium*, *Triloculina*, *Quinqueloculina* and *Lachlanella)* exhibited mild to severe deformities (Appendix 1-4) such as fusion of two adults or double tests, protuberance(s) on the spiral side, abnormal arrangement of the chambers, abnormal shape of the proloculus, and modification of the coiling plane in several chambers (Figure 31). *Peneroplis* (58.4%) and *Coscinospira* (17.1%) accounted for 75.5% of all the observed test deformities.

Table 5. Total benthic foraminiferal relative abundances (%) of specimen picked and counted. The values of each species is expressed as a percentage composition per station

Species/Stations	1A	2A	2C	3A	4A	5A	6A	7A	8A	9A	10A
Taxa_S	26	26	27	31	26	25	25	20	23	21	9
Individuals	644	332	515	551	446	334	194	164	236	256	121
Dominance_D	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3
Shannon_H	2.4	2.2	2.3	2.9	2.8	2.8	2.7	2.5	2.5	2.2	1.6
Evenness_e^H/S	0.4	0.4	0.4	0.6	0.6	0.7	0.6	0.6	0.5	0.4	0.6
Agglutinella robusta	0.00	0.00	0.00	0.18	0.00	0.00	0.52	0.00	0.00	0.00	0.00
***Adelosina* sp.**	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00
Agglutinella soriformis	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
***Lachlanella* sp**	0.00	0.60	0.39	2.18	0.45	0.90	1.03	0.00	0.00	0.00	0.00
lachlanella corrugata	1.24	1.51	3.30	0.91	0.67	0.00	0.00	0.00	0.00	0.00	0.00
Miliolinella cf. M. circularis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miliolinella fusca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
***Miliolinella* sp. 1**	1.24	0.00	1.75	5.81	0.45	1.50	0.00	1.83	0.85	0.00	0.00
***Miliolinella* sp. 2**	0.31	0.00	0.00	0.36	0.00	0.30	3.09	0.61	0.42	0.78	0.00
***Miliolinella* sp. 3**	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
***Miliolinella* sp. 4**	0.00	0.90	2.14	4.54	0.00	0.00	1.03	1.83	0.85	1.56	0.00
***Pseudotriloculina* sp. 1**	0.47	0.60	2.91	1.45	1.35	3.29	1.55	0.00	1.27	0.00	0.83
Pseudotriloculina subgranulata	0.00	0.60	0.39	0.18	1.57	0.00	0.00	0.00	0.42	0.00	0.00
Quinqueloculina quinquecarinata	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00
Quinqueloculina carinatastriata	1.09	1.51	0.58	3.27	0.45	0.90	0.00	1.22	0.00	0.00	0.00
Quinqueloculina seminulum	1.71	3.01	1.55	2.54	1.35	1.50	3.09	3.05	0.00	0.00	0.00
Quinqueloculina lamarckiana	0.62	0.90	0.00	0.00	0.90	0.00	0.00	0.00	1.69	0.39	0.00
***Quinqueloculina* sp. 1**	2.33	2.41	1.17	3.09	4.26	5.09	9.28	7.93	2.54	1.56	8.26
***Quinqueloculina* sp. 2**	0.62	0.90	1.17	2.90	1.79	4.19	1.03	3.05	3.81	1.95	3.31
***Quinqueloculina* sp. 3**	2.48	1.20	0.00	0.36	2.69	1.80	5.67	3.05	1.69	2.34	2.48
***Quinqueloculina* sp.4**	2.48	1.20	3.69	3.27	0.00	0.00	2.06	0.61	3.81	3.13	0.00
Quinqueloculina bicarinata	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Triloculina* aff *T. vespertilio	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00
Triloculina* cf *T. affinis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
***Triloculina* sp.**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.39	0.00
Triloculina* cf *T. asymmentrica	0.00	0.00	0.00	0.91	0.22	0.90	0.00	0.00	0.00	0.00	0.00
Triloculina* cf *T. fichteliana sp. 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coscinospira hemprichii	12.58	22.29	26.21	5.44	3.14	1.80	6.70	4.27	5.93	1.17	0.00
Coscinospira acicularis	3.73	0.60	1.17	2.36	0.45	0.60	0.00	0.61	1.27	2.34	0.00
Coscinospira arietina	4.97	4.22	5.83	5.26	0.67	1.20	2.06	4.27	1.27	0.00	0.00
Peneroplis pertasus	26.09	31.63	28.35	23.96	14.80	17.96	12.89	25.00	23.31	28.91	37.19
Peneroplis planatus	22.52	15.66	8.74	6.17	15.02	9.88	18.56	15.85	21.19	29.30	32.23
Ammonia convexa	5.75	2.71	3.50	3.81	9.64	8.98	10.82	5.49	12.29	6.64	5.79
***Ammonia* sp. 1**	0.47	1.20	0.39	0.91	6.28	3.89	0.00	0.00	0.00	0.78	0.00
***Ammonia* sp. 2**	1.09	0.30	0.58	1.09	1.35	3.29	0.00	4.88	0.00	0.39	0.00

Ammonia tepida	1.71	0.00	0.58	1.81	5.83	5.69	4.64	1.83	2.12	5.47	3.31
Elphidium craticulatum	0.93	0.60	0.78	2.18	8.74	5.99	4.64	4.27	5.08	3.13	0.00
Elphidium stratiopunctatum	0.78	0.90	0.39	1.45	2.02	2.10	0.52	0.00	0.85	0.00	0.00
***Elphidium* sp. 1**	1.24	0.30	0.19	1.27	6.95	8.98	0.00	0.00	2.12	4.30	6.61
Elphidium fichtellianum	0.00	0.30	0.39	1.09	0.00	0.00	0.52	0.00	0.00	0.39	0.00
Elphidium advenum	1.40	2.11	1.17	6.35	4.04	5.09	6.19	7.32	3.39	3.52	0.00
Elphidium gerthi	1.55	1.81	2.33	4.54	4.93	3.89	2.06	3.05	2.97	1.56	0.00
***Rosalina* sp.**	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00
Clavulina angularis	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

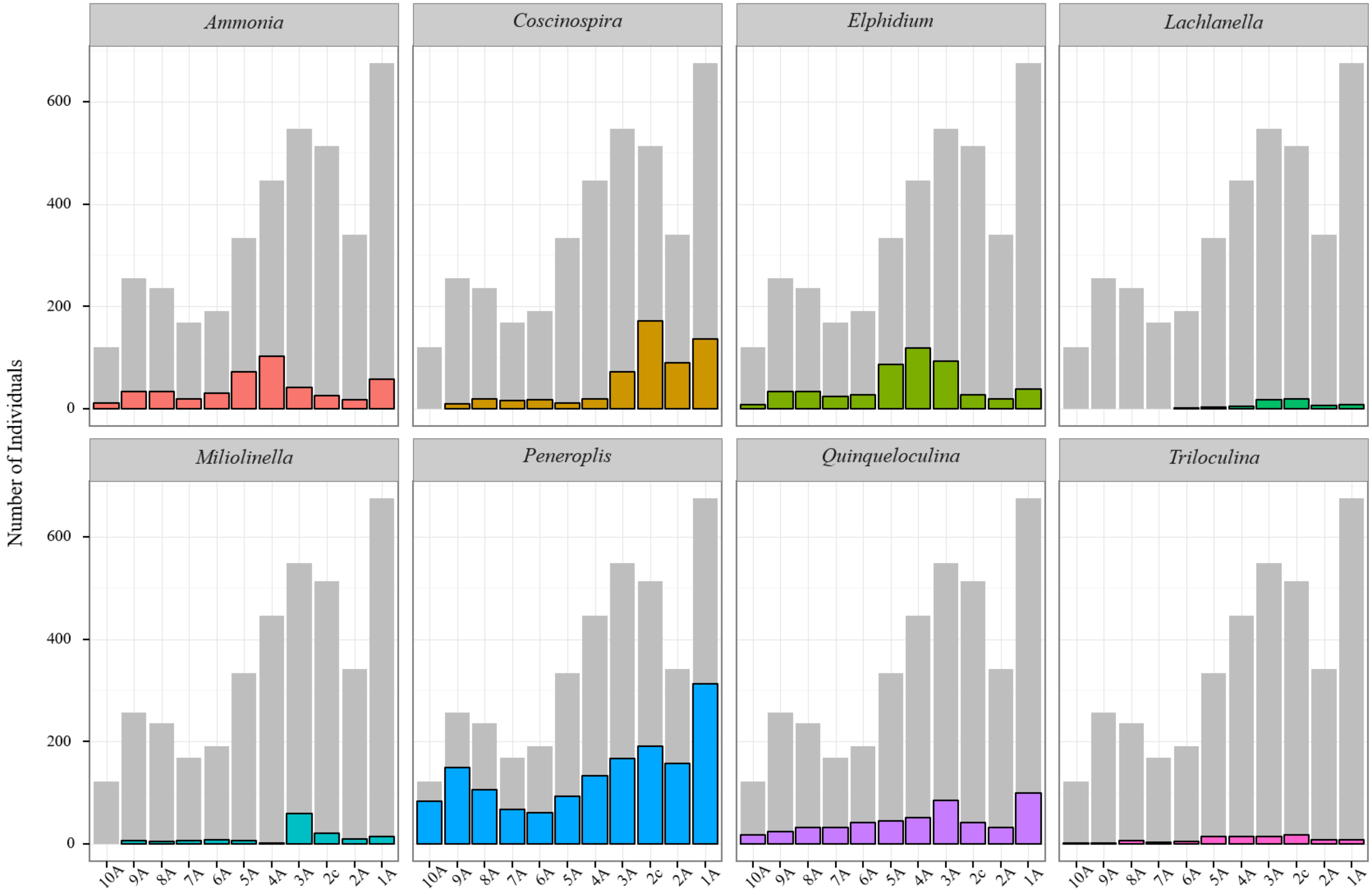

Figure 15. Distribution of foraminifera along the transect sampled. Grey bars represent the total for each station while colored bars denote the dominant genera in this study.

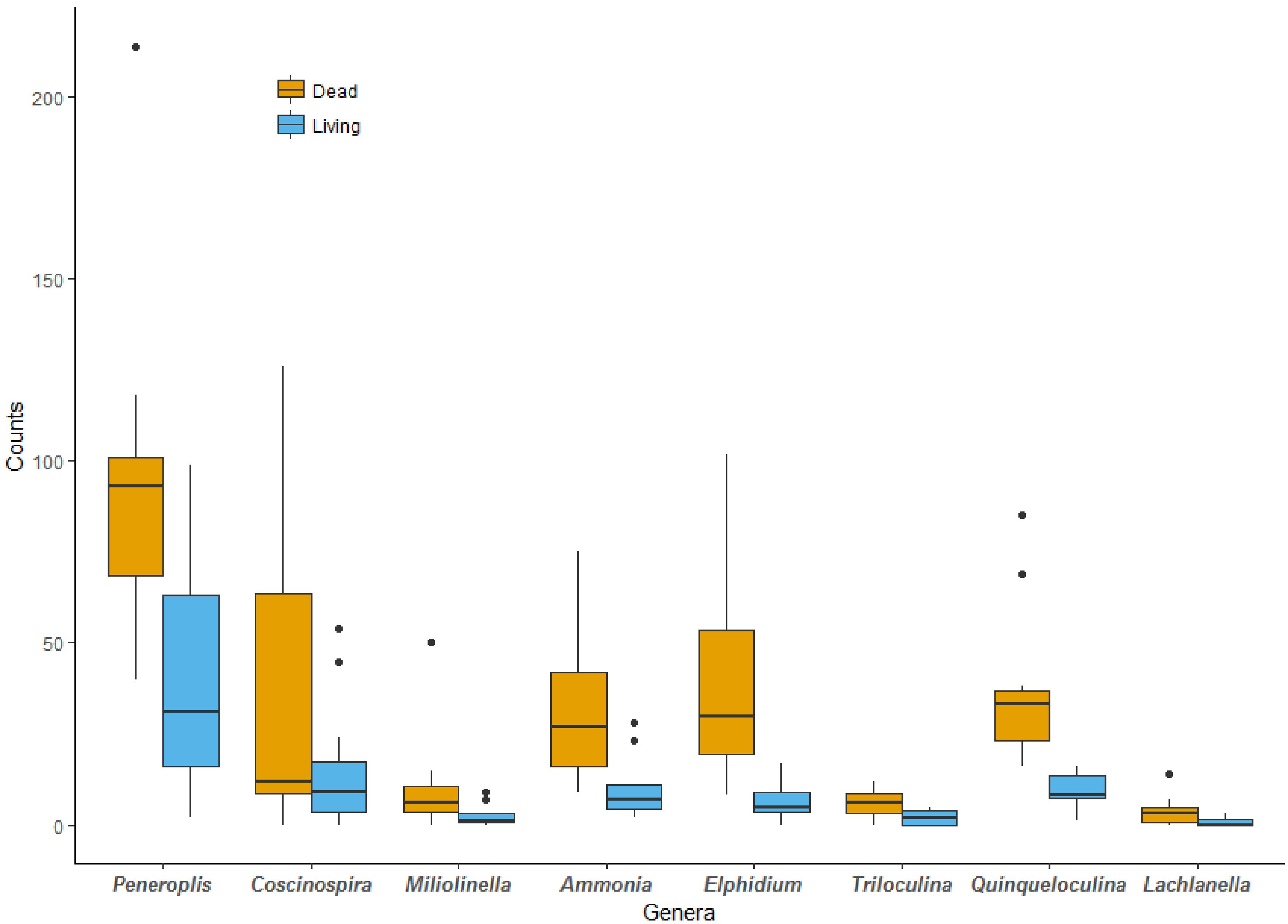

Figure 16. Counts of living (Rose Bengal stained) to dead foraminifera for all the stations along the sampled transect.

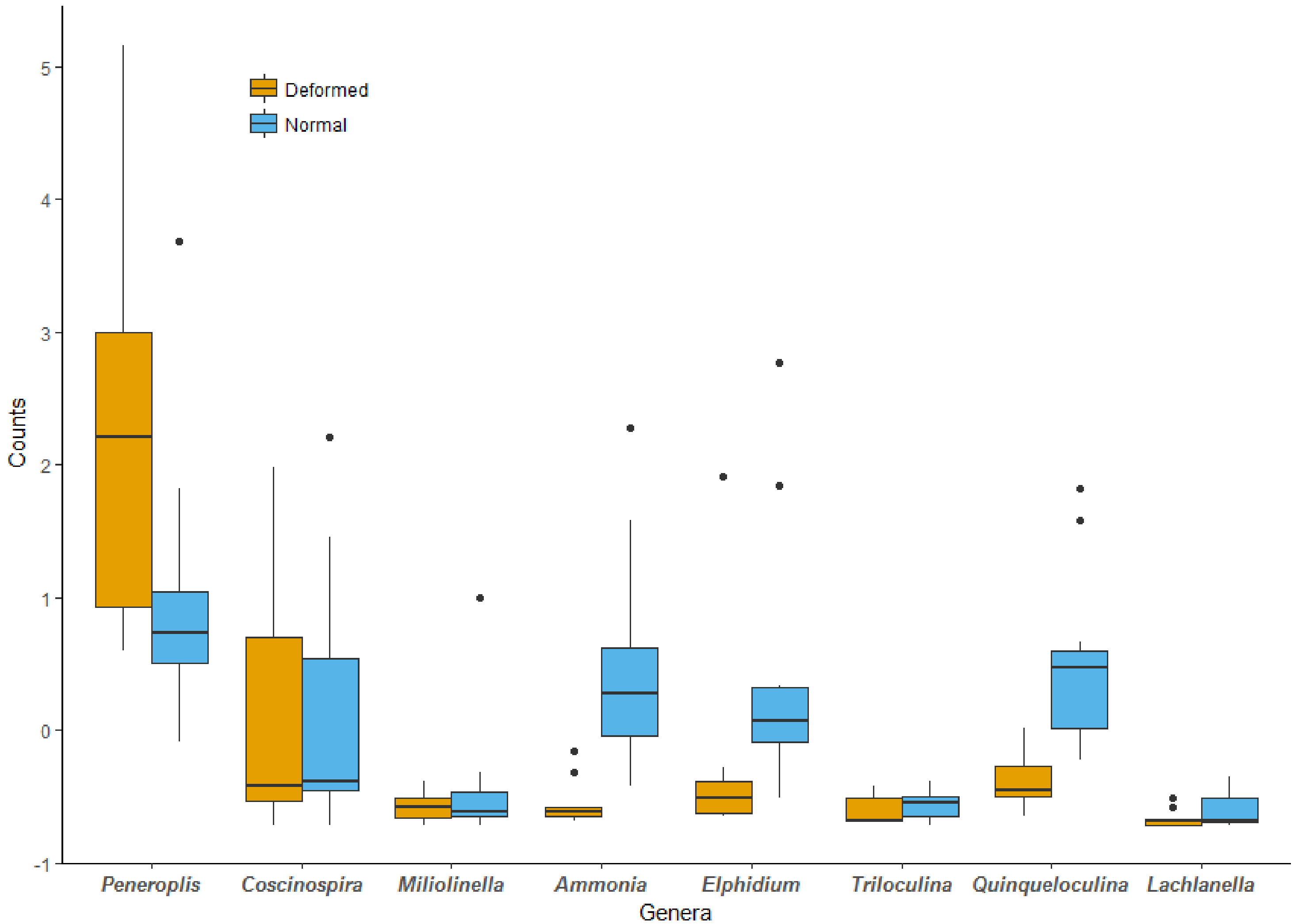

Figure 17. Proportions of normal to aberrant test for all the stations along the transect.

Figure 18. 1a-c ***Peneroplis planatus* with double tests,** 2a-c ***Peneroplis planatus* with modification of the coiling plane** 3a-c**, *Peneroplis planatus* with "normal" test,** 4a-c ***Coscinospira hemprichii* with modification of the coiling plane,** 5a-c ***Coscinospira hemprichii with* abnormalities of middle chambers,** 6a-c ***Coscinospira hemprichii* with "normal" test showing somewhat twisted chambers,** 7a-c ***Peneroplis pertusus* with duplication of last chamber,** 8a-c ***Peneroplis pertusus* with bifurcation of the final apertural chamber,** 9a-c ***Peneroplis pertusus* with "normal" test showing depressing of the last chambers. All scale bars are 100 µm.**

6.4 Discussion

The main focus of this study was to document benthic foraminiferal diversity and quantify the test abnormalities of different taxa in the Salwa Bay area so as to understand the impacts (if any) of natural processes on the faunal composition. As such, it was important to document environmental parameters (sediment and water) to exclude the influences of anthropogenic pollutants and nutrients known to significantly contribute to test deformities in foraminifera (Yanko et al., 1994, 1998; Frontalini et al., 2009; Frontalini and Coccioni, 2011). Care should be taken in interpreting living assemblage because our study is based on a single sampling event during summer and, except for station 2, replicates were not analyzed. Therefore, the extent of patchiness in the foraminiferal distribution was not determined. In addition, the deformity data reported takes into account only the time averaged, well-preserved specimens. Extensively degraded and mechanically eroded specimens were excluded from these data to reduce bias. We argue however, that our data (samples and stations) are sufficiently statistically robust for the Salwa Bay area to warrant the following interpretation.

6.4.1 Environmental Data

Salwa Bay is generally characterized by shallow depths and clear oligotrophic waters, as the entire area lies within the photic zone, as is typical of most undisturbed shallow areas of the Gulf (Murray, 2006). The mean temperature we recorded is low compared to other studies in the area, likely due to the time of the day that I conducted sampling (8 AM–12.00 noon). Joydas et al. (2015) reported a peak temperature of 40°C on a hot summer afternoon in the same area sampled. The salinity reported is very high 52.6 ± 0.4, reflecting the highly restricted paralic environments in the Arabian Gulf. Higher salinities (60 ppt) have been reported in the Salwa Bay area (Joydas et al., 2015).

The sediments along the sampled transect are homogeneous, composed largely of moderate- to well-sorted sand indicative of aeolian sand deposits from nearby coastal dunes in the area. This sediment type is also a common feature of wave-dominated shorelines along the west coast of the Gulf. Benthic foraminiferal community structure and composition are known to be influenced by grain size, type and distribution (Arslan et al., 2015). Biogenic fragments of cerithiid gastropod shells, typical of hypersaline restricted environments of the western Arabian Gulf (Amao et al., 2016b; Murray, 1966a, 1966b, 1965a), are largely absent. We interpret this absence to be the influence of relatively high wave energy and the lack of suitable flora upon which they feed on in the area. In addition, the environment might only be suitable for epifaunal habits (epilithic or epilithic) due to the lithified hardgrounds characteristic of the sampled area.

We observed very low concentrations of heavy metals, PAH, TPH and nutrients, the presence of which would be indicative of a polluted environment. This is consistent with absence of significant human activities and settlement in the area. The low values of these proxies might also be due to the known affinity of metals to finer particles (Contu et al., 1984; Rao et al., 2008). The considerably low TOC values are attributed to the dominant coarse sediments, as TOC is usually more highly concentrated in fine grained or mud-rich sediments than in coarse-grained sediments (Martins et al., 2011). The Arabian Gulf water is naturally rich in dissolved solids (TDS), cations and anions owing to the geology of the area, high evaporation rates, and the arid climatic conditions prevalent in the area.

6.4.2 Diversity of benthic foraminifera

The diversity of benthic foraminifera in the Salwa Bay is paucispecific and dominated by large benthic foraminifera (*Peneroplis* and *Coscinospira*) that are known to acclimatize to high salinity and temperature in the shallow, restricted environments of the western and southern Arabian Gulf (Amao et al., 2016; Clarke and Keij, 1973; Murray, 1966a, 1966b, 1966c, 1965a, 1965a; Murray, 1970). The known ecology of these taxa (epifaunal) also suggests that they are better able to anchor to hard substrates (epilithic) against the impacts of the relatively high wave energy in the area (Murray, 2006). An opportunistic taxon (*Ammonia*) has a considerable representation probably due to its ability to reproduce rapidly and their niche requirements (Frontalini et al., 2009; Murray, 2006). It is possible however, considering the living specimens, *Ammonia* is not that abundant and most of their tests are normal. This may suggest that they reproduced and grew before summer when the conditions were less extreme.

The dominance of miliolids among the living forms documented (Figure 28) is largely due to the hypersaline conditions in the absence of organic pollution, eutrophication, or other nutrient enrichment sources in the area. Arslan et al. (2015) reported a general negative relationship between the relative abundances of miliolids and organic matter pollution in a seasonality study based on samples collected from a shallow environment on the east coast of Bahrain, north of the current study area. Deformity rates and types are disproportionately high among the larger benthic foraminifera (Figure 29); this may be interpreted in light of their modes of life and feeding. On the other hand, smaller benthic foraminifera dominated by rotaliids, have low deformity rates. Their life strategies (mostly infaunal and free living) ensure that they can survive unfavorable conditions. The amount of reworked fauna increases in the shoreward direction, owing to the higher hydrodynamic energy closer to the beach.

6.5 Conclusions

In this study, we investigated the benthic foraminiferal diversity and quantified the test abnormalities of different taxa in the Salwa Bay area, to compare with a previous study by Clarke and Keij (1973) and to understand the impacts (if any) of natural processes on the faunal composition. We observed high numbers but low diversity of foraminifera in the sampled transect. We found low TOC, heavy metals, and pollution-derived nutrient concentrations in the investigated site. A disproportionately high deformity rates is found among the large benthic foraminifera. We also observed a considerably high proportion of living (Rose Bengal stained) taxa in the identified foraminiferal population. We therefore conclude that the percentage of abnormality, if applied to the Salwa Bay for pollution studies, might not be a useful environmental proxy due to the high background deformity rates documented in this study.

A useful environmental proxy will take into account the health, composition, and structure of the benthic foraminiferal community in the area. A decrease in the dominance of miliolids (e.g., *Peneroplis* and *Coscinospira*) and an increase in the numbers of opportunistic taxa (e.g., *Ammonia* and *Elphidium*) should be a better indicator of the health of the environment. The dominance of *Peneroplis* and *Coscinospira,* as suggested by Murray (1970b) and Clarke and Keij (1973), can be used to delineate restricted environments from normal ones in the Arabian Gulf. In comparison with our previous study in Bahrain (Amao et al., 2016b), the occurrence of large numbers of *Coscinospira acicularis* and *C. arietina,* in conjunction with a high abundance of peneroplids, better reflects the salinity level. *Coscinospira acicularis* and *Coscinospira arietina* have higher relative abundances in salinities >52 ppt.

CHAPTER 7

Diversity of Foraminifera in a shallow restricted lagoon in Bahrain

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SUMMARY-- We document the foraminiferal diversity across a semi-enclosed pool in eastern Bahrain that we named "Murray's Pool" because this is the same location as the one studied by Basson and Murray (1995), the only previous study of foraminifera in this sector of the Arabian Gulf. We subdivided the sampling area into six subenvironments based on distinguishable physical environmental features, namely tidal channel, tidal flat, *Salicornia* marsh, algal mat, sheltered inner lagoon, and back marsh pool. Faunal analysis from these six shallow-water subenvironments reveals two main assemblages of benthic foraminifera: an *Ammonia convexa-Elphidium advenum-Peneroplis pertusus* assemblage and an *Ammonia convexa-Coscinospira hemprichii-Peneroplis pertusus* assemblage. The most abundant species across all the subenvironments are *Peneroplis pertusus*, *Ammonia convexa*, *Coscinospira hemprichii*, and *Elphidium advenum*. Species assemblage composition and percentage abundances were determined for each subenvironment; the tidal flat subenvironment shows the highest total abundance, but has twenty-four fewer species compared to the sheltered inner lagoon. We also noted the proportions of living foraminifera and juveniles in all the subenvironments to understand the distribution of biofacies within the lagoon. The numbers of juvenile miliolid foraminifera are highest in the tidal channel and the two adjacent subenvironments of the tidal channel.

7.1 Introduction

The earliest comprehensive studies of lagoonal foraminifera and other paralic environments in the Arabian Gulf were undertaken by Murray (1965a, 1965b, 1966a, 1966b, 1966c, 1970a, 1970b). As early as in the 1970's, Prof. Murray documented the difficulty in finding an undisturbed sampling locality due to massive dredging activities and rapid urbanization, and warned of destruction or disappearance of such environments. The original localities for Murray's studies are currently locations of megacities, parks and resorts. The situation has been persistent and is echoed throughout all the states bordering the Arabian Gulf. In the area of the Kingdom of Bahrain, Basson and Murray (1995) published the only study of lagoonal foraminifera. Their study reported a 25-month sampling event on the eastern coast of Bahrain (Text-fig. 1) and documented the temporal variation of four benthic foraminiferal species inside the lagoon, but their study did not include an exhaustive survey of the foraminiferal fauna.

The fragile marine ecosystem of the Arabian Gulf is facing growing threats from intensive development projects. Coastal land in Bahrain for example, is at a premium due expansion of housing, transport, and recreational facilities projects. The rate of shallow coastal and tidal flat reclamation between 1997–2007 is estimated at an alarming rate of 21 km^2/year (Figure 32), and the cumulative loss of major habitats resulting from 10 reclamation projects alone was responsible for the loss of over 153.58 km^2 (Sheppard et al., 2010; Zainal et al., 2012). Also, the Arabian Gulf environment still is recovering from the devastating impact of the 1991 Gulf war oil spill, and ongoing anthropogenic influences are threatening the surviving patches of land that missed the wrath of the spill.

The Arabian Gulf[1] is known to be the most extensive stretch of hypersaline shelf on earth and is unique for its endemic flora and fauna that have adapted to extremes of salinity and temperature (Murray, 1991; H. Naser, 2011). The area appears to be largely undocumented in a micropaleontological sense. In this study, we surveyed a semi-enclosed lagoon that we named "Murray's Pool" because this is the same location studied by Basson and Murray (1995). The lagoon is located at the southern edge of Askar fishing town, and borders with the Bahrain Department of Mariculture centre. The site is now under threat by developers who are in the process of extending the seafront park on the south side of the town of Askar.

Benthic foraminifera have been used as proxies for monitoring contemporary environmental changes (Debenay et al., 2001b; Debenay and Luan, 2006; Coccioni et al., 2009; Frontalini et al., 2009, 2010, 2011, 2013; Bouchet et al., 2012; Mateu-Vicens et al., 2014) and recently, they have also been used as indicators of recent tsunami and storm overwash, i.e., by documenting allochthonous tests in coastal lagoons, ponds and marshes (Pilarczyk et al., 2011). Studies of modern Foraminifera are also necessary to assist in the palaeoecological interpretation of ancient limestones and their included faunas (Murray, 1970a). Therefore, as part of a larger research effort to document the distribution, taxonomy and ecology of foraminifera in the Arabian Gulf, the purpose of this study is to survey the foraminiferal biofacies, abundance, and diversity across the lagoon.

[1] Also known as Persian Gulf

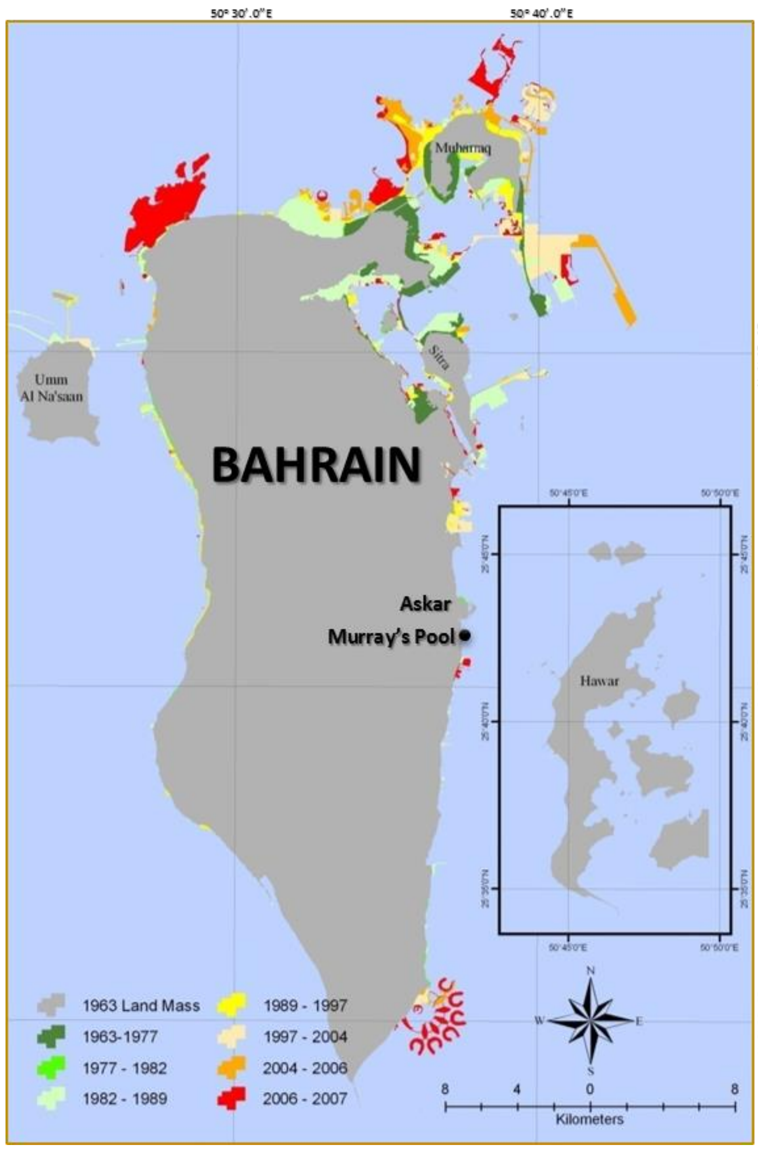

Figure 19. Reclaimed sea land around the coastal areas of Bahrain during 1963–2007 with the location of "Murray's pool" indicated (modified from Zainal et al. 2012)

7.2 Methodology

7.2.1 Location

Murray's pool is a small lagoon covering an area of ≈ 36,000 m^2 with an inlet channel linking it to the Arabian Gulf. Rapid expansion of a sea front park has progressively affected the size of the lagoon (Figure 33). The lagoon is located at latitudes 26.044596°–26.043362° and longitudes 50.622719° –50.625806° (Figure 33b). The lagoon has a gentle sloping topography draining into the inlet channel and the water depth from the channel to the interior of the lagoon range from 2 to 40 cm, i.e., depth increases towards the channel from the lagoon interior and the tidal flat (Figure 33c). Tidal flat and surrounding subenvironments have sparse vegetation comprising small herbaceous halophyte (*Salicornia* sp.), filamentous algae, and slimy cyanobacteria.

The average salinity and water temperature measured for the pool between June 2014 and April 2015 is 43–47 ppt for Murray's Pool, 43–45 ppt for open marine water outside the pool (26°02'40.1"N, 50°37'35.2"E), and 26–28°C respectively. The region, due to its arid climate is characterised by high air temperature, evaporation rates, relative humidity, strong winds, and low precipitation (Abdalla, 1994; Joydas et al., 2015). The region experiences mixed tidal regimes, which is predominantly semi-diurnal, and yielding two unequal tides each day (Joydas et al., 2015).

7.2.2 Sampling

Our sampling efforts from Murray's pool involved several weekend trips to Bahrain starting in the autumn (September) of 2013. This was aimed at detecting changes to the physical environment and seasonal differences in the foraminiferal populations (Arslan et al., 2016). In the current study the samples collected during a one sampling event in winter (December) of 2014 are investigated. During this field survey, a 20 cm^3 sediment sample was collected from the top 2 cm sediment surface layer at each station representing six subenvironments, namely tidal channel, tidal flat, *Salicornia* marsh, algal mat, sheltered inner lagoon, and back pool within the lagoon (Figure 33). An initial challenge earlier in this study was how to preserve foraminiferal samples in ≥70% ethanol so as to study the living foraminifera and cross the Saudi–Bahrain border without breaking any laws. Possession, consumption, or transportation of alcohol is strictly forbidden in Saudi Arabia. The exception to this rule, is industrial/laboratory grade alcohol (90–98% ethanol), which is regulated by the government and must originate from a local supplier and used within the Kingdom.

We collected samples and preserved them using 50% ethanol (Smirnoff Black vodka) and also tested 38% ethanol (Gin), and the result was promising except for few cases (samples) where the Gin-Rose Bengal solution indiscriminately stained both living and dead foraminifera. These samples were not used in this study because of the challenge of staining samples and washing off the preservative before crossing the Saudi border, but they form the basis of our interest and knowledge of the area. Subsequently, samples were collected in 120 ml jars, then immediately transported across the border and preserved using laboratory-grade ethanol (70%) with Rose Bengal stain for two weeks. A study comparing methods to distinguish live from dead foraminifera by Bernhard et al. (2006) showed that less than half of the Rose Bengal-stained benthic foraminifera were actually alive at the time of collection, and thus we consider that effect of cytoplasmic degradation during transportation on the reliability of a viability test using Rose Bengal was kept minimal. In the laboratory, samples were wet-sieved through a 63 µm mesh sieve, dried, and later split into equal aliquots to generate subsamples with approximately 300 benthic foraminiferal tests (total assemblage) using a microsplitter to ensure unbiased split. Specimens were picked quantitatively from the 63 µm fraction to include juveniles.

Hydrographical parameters of the water, i.e., temperature and salinity, were determined using a portable thermometer (9842 Taylor® pro waterproof instant read thermometer) and refractometer (ATC RF20-Salt); capable of measuring salinity between 0 to 100 ppt with an accuracy of ±0.1‰ respectively. Species present were illustrated using scanning electron microscopy (JEOL JSM-5900LV) at the Earth Sciences Department, King Fahd University of Petroleum & Minerals in Dhahran, Saudi Arabia. Assemblage composition and relative percentage abundances were determined for each subenvironment based on the recommendations of (Hayek and Buzas, 2013).

7.2.3 Taxonomy and systematics

Identification of foraminifera in this study was aided by the monographs of Zheng (1988), Hottinger et al. (1993), Albani and Yassini (1993), Cherif et al. (1997), Hayward et al. (1999, 1997), Parker (2009) and Debenay (2012). When these references proved insufficient, the classic books of McCulloch (1977) and Loeblich and Tappan (1994) were consulted for generic level identification. The faunal reference slides are currently housed in the author's collection at KFUPM. These will be permanently archived in the European Micropaleontological Reference Center at Micropress Europe in Kraków, Poland.

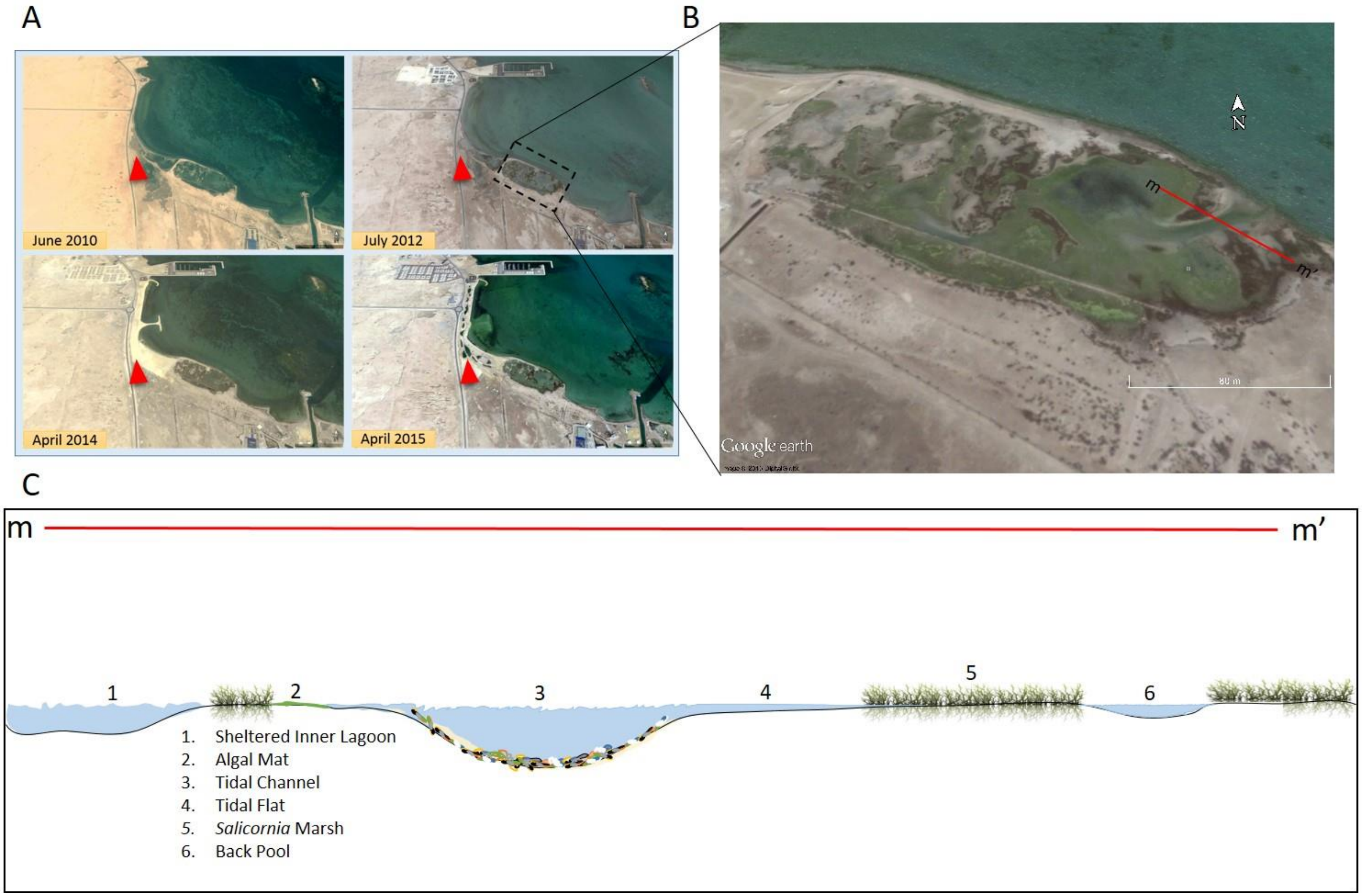

Figure 20. A. Satellite images demonstrating changes around Murray's Pool between 2010 and 2015 with inserted solid triangle pointing towards areas with noticeable rapid changes at the middle of the images. B. Zoomed in area of Murray's Pool showing the tidal channel and location for the sampled transect which is elaborated in (c). C. A schematic cross section (not to scale) of Murray's Pool drawn to show the detailed subenvironments. The redline shown (m-m') is a profile across all the subenvironments

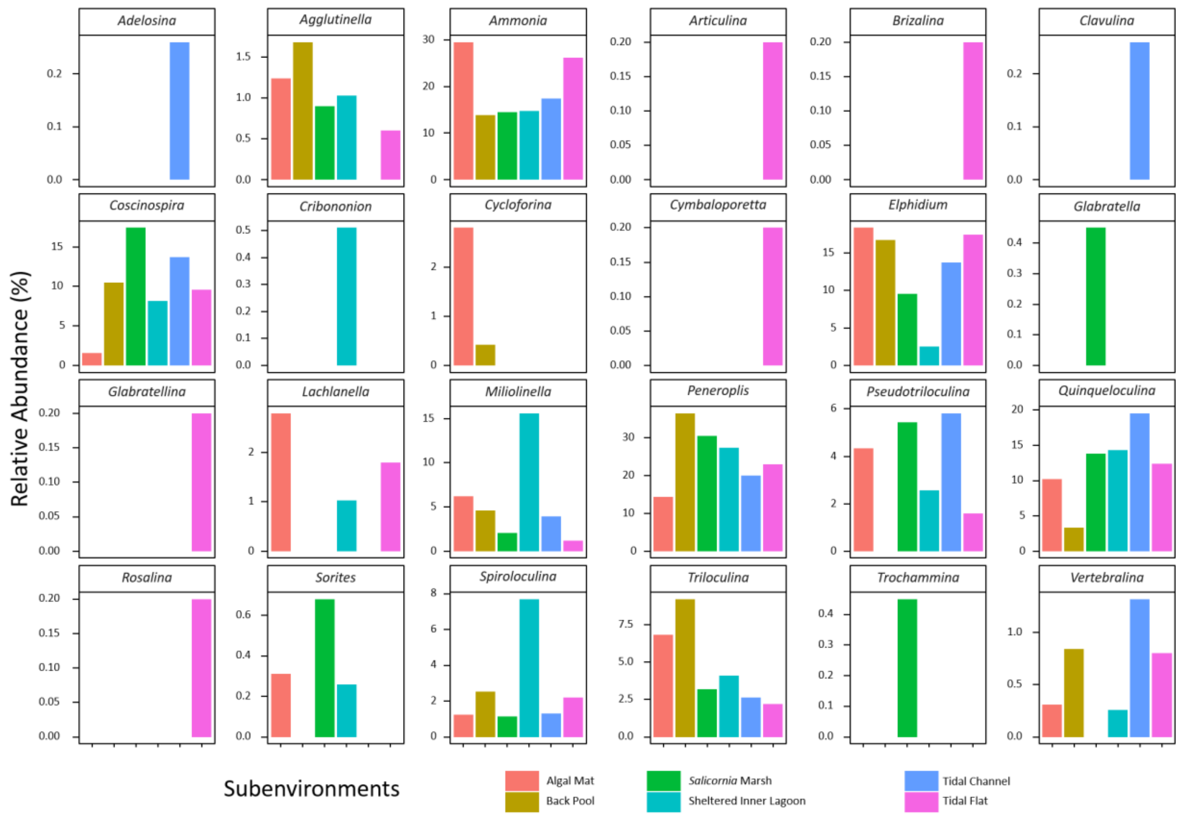

Figure 21. Summary of the distribution of major groups of foraminifera by genera found in Murray's Pool, each plot with its own y-axis scale, x-axis represents the sub-environments

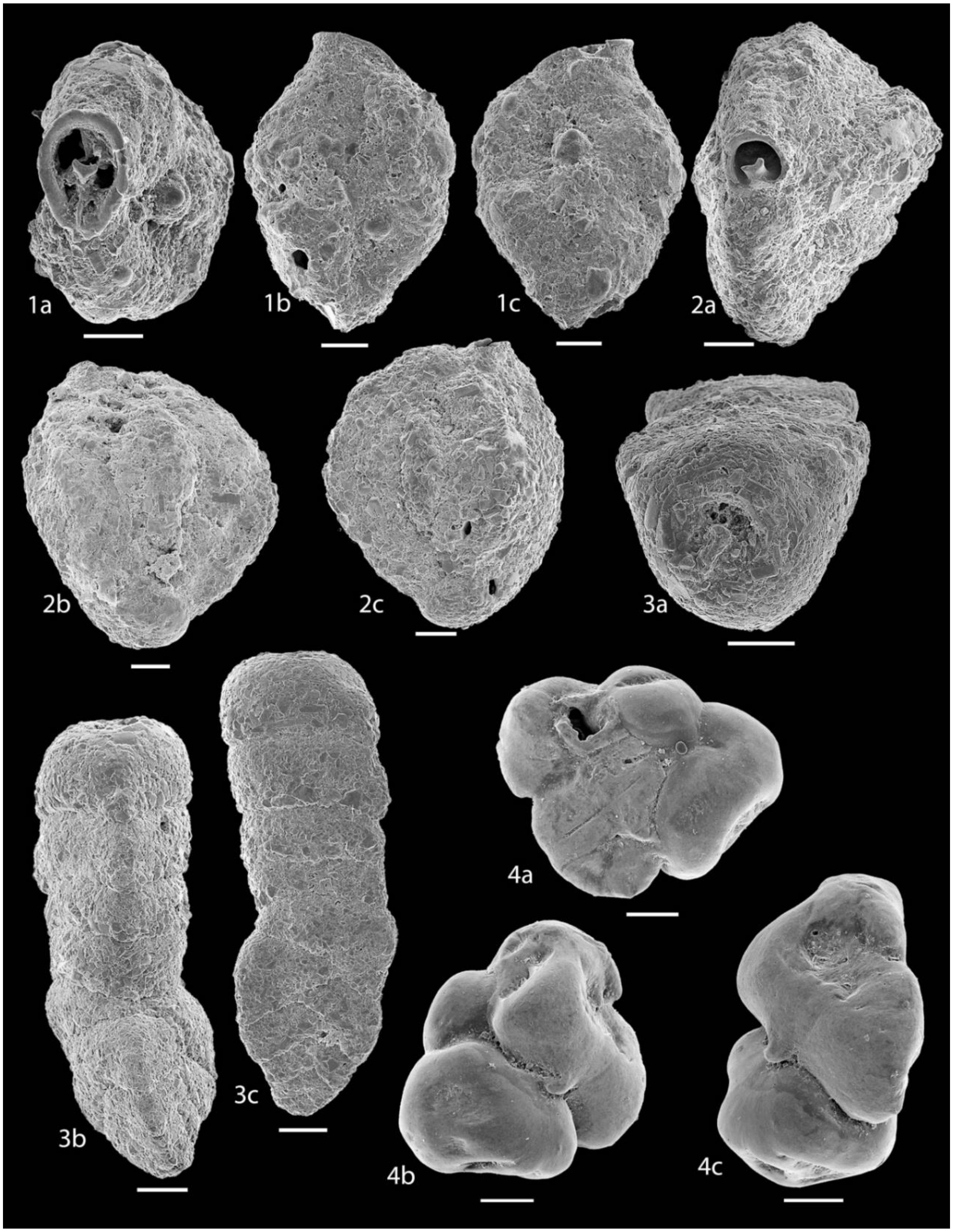

Figure 22. 1a-c *Agglutinella soriformis*; (a) apertural view (b) lateral view of more involute side (c) lateral view of more evolute side. 2a-c, *Agglutinella aggutinans* (a) apertural view (b) lateral view of more involute side (c) lateral view of more evolute side. 3a-c *Clavulina angularis* (a) apertural view (b) lateral view of more involute side (c) lateral view of more evolute side. 4a-c *Miliolinella* sp. 6. (a) apertural view (b) lateral view of more evolute side (c) lateral view of more involute side. All scale bars are 100 µm.

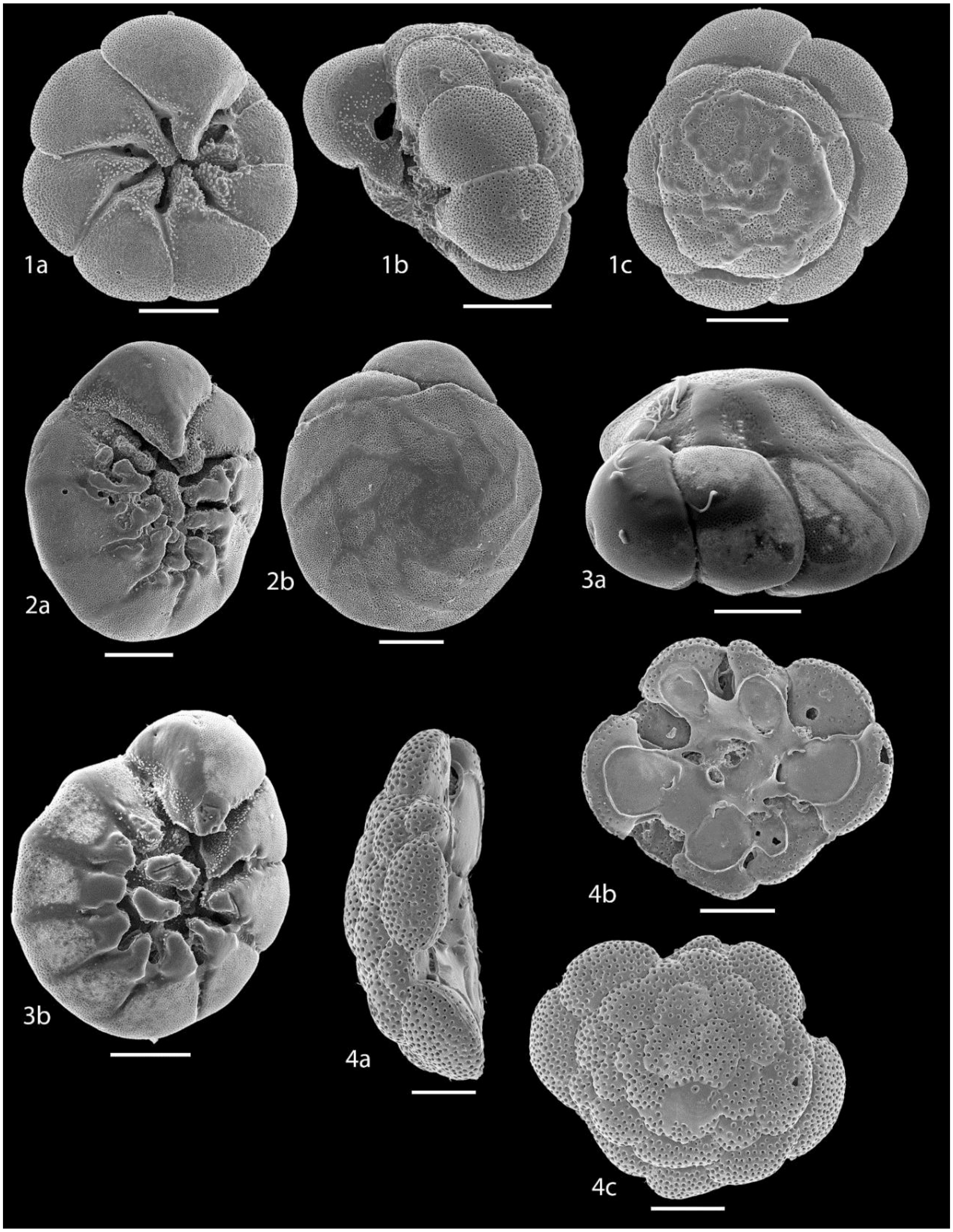

Figure 23. 1a-c *Ammonia tepida*, (a) umbilical view (b) apertural view (c) spiral view. 2a-b *Ammonia* sp. 1, (a) umbilical view (b) spiral view. 3a-b *Ammonia convexa* (a) spiral view (b) umbilical view. 4a-c *Cymbaloporetta bradyi* (a). Side view ((a) umbilical view (c) spiral view. All scale bars are 100 µm

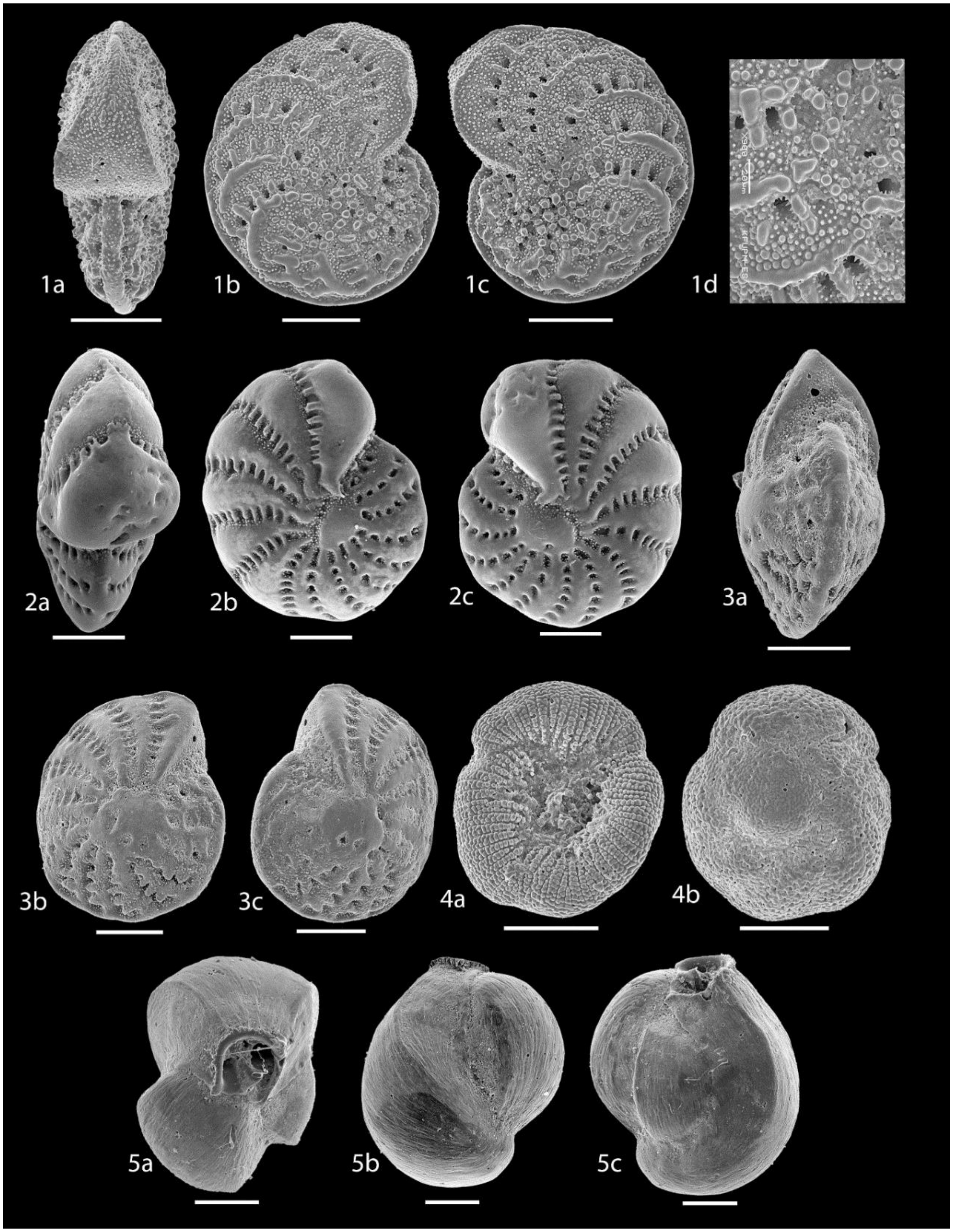

Figure 24. 1a-d *Elphidium jenseni* (a) peripheral view (b) lateral view (c) lateral view of the opposite side (d) zoomed in area showing pseudospines projecting into the fossettes. 2a-c *Elphidium* cf. *E. gerthi* (a) peripheral view (b) lateral view (c) lateral view of the opposite side. 3a-b *Elphidium advenum* (a) peripheral view (b) lateral view (c) lateral view of the opposite side. 4a-c ?*Glabratella* sp. 1 (a) umbilical view (b) spiral view. 5a-c *Triloculina* cf. *T. serrulata* sp. 1; (a) apertural view (b) lateral view of more involute side (c) lateral view of more evolute side. All scale bars are 100 µm.

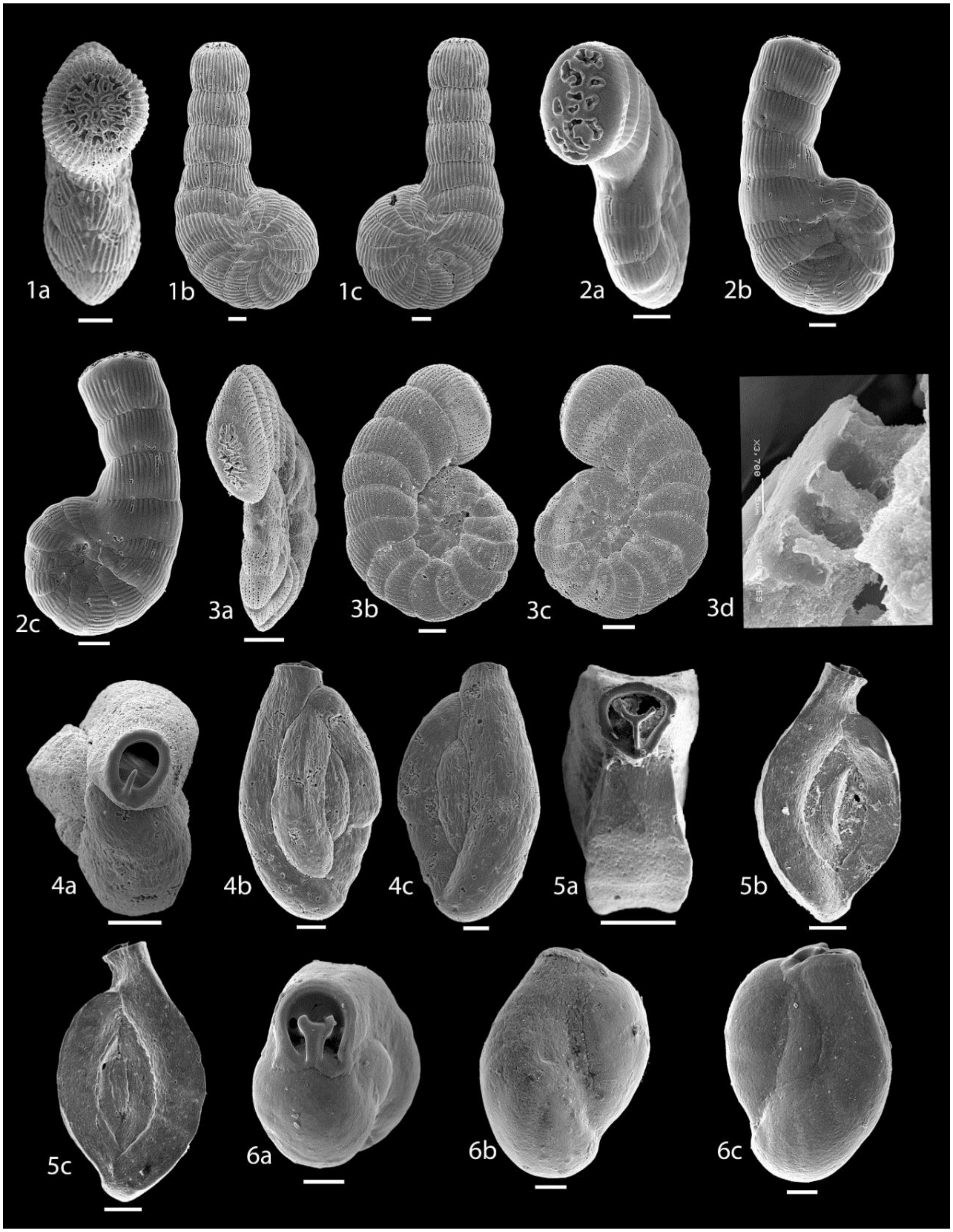

Figure 25. 1a-c *Coscinospira hemprichii* (a) apertural view (b) lateral view (c) lateral view of the opposite side. 2a-c *Coscinospira* sp. 1 (a) apertural view (b) lateral view (c) lateral view of the opposite side. 3a-d *Peneroplis arietinus* (a) apertural view (b) lateral view (c) lateral view of the opposite side (d) zoomed area showing surface pores. 4a-c *Quinqueloculina* sp. 7 (a) apertural view (b) lateral view of more evolute side (c) lateral view of more involute side. 5a-c *Spiroloculina* cf. *S. communis* (a) apertural view (b) lateral view of more involute side (c) lateral view of more evolute side. 6a-c *Pseudotriloculina subgranulata* (a) apertural view (b) lateral view of more involute side (c) lateral view of more evolute side. All scale bars are 100 µm.

Table 6. Summary of diversity indices, counts, abundances and species richness

Diversity Indices	Sheltered Inner Lagoon	Algal Mat	Tidal Channel	Tidal Flat	Salicornia Marsh	Back Pool
Number of taxa, S	64	37	40	49	33	30
Number of total adult individuals	392	322	379	500	442	239
Dead specimens (juveniles and adults)	219	410	240	410	290	182
Living specimens (juveniles and adults)	196	105	218	367	209	98
Ratio of living/dead (juveniles and adults)	0.89	0.26	0.91	0.90	0.72	0.54
Ratio total juvenile to total adults***	0.06	0.60	0.21	0.55	0.13	0.17
Number of specimens picked	415	515	458	777	499	280
Number of specimens per cc	166	206	183	311	133	56
Juvenile porcelaneous*	23	193	79	277	57	41

* Mainly juveniles of *Quinqueloculina*, *Triloculina* and *Miliolinella (dead and living)*

*** Total means total of *dead and living*

Table 7. Percentage relative abundances calculated as number of individuals per samples divided by the total of individuals in the sample

Species	**Sheltered inner Lagoon**	**Algal Mat**	**Tidal Channel**	**Tidal Flat**	***Salicornia* Marsh**	**Back Pool**
Adelosina cf. A. mediterranensis	0.00	0.00	0.26	0.00	0.00	0.00
Agglutinella aggutinans	0.00	0.62	0.00	0.00	0.00	0.00
Agglutinella arenata	0.26	0.62	0.00	0.40	0.45	1.26
Agglutinella compressa	0.51	0.00	0.00	0.20	0.00	0.00
Agglutinella robusta	0.26	0.00	0.00	0.00	0.00	0.42
Agglutinella soriformis	0.00	0.00	0.00	0.00	0.45	0.00
Ammonia convexa	14.80	18.94	15.04	19.00	12.22	11.72
Ammonia sp. 1	0.00	0.00	0.53	0.00	0.00	0.00
Ammonia tepida	0.00	10.56	1.85	7.20	2.26	2.09
Articulina pacifica	0.00	0.00	0.00	0.20	0.00	0.00
Brizalina striatula	0.00	0.00	0.00	0.20	0.00	0.00
Clavulina angularis	0.00	0.00	0.26	0.00	0.00	0.00
Coscinospira hemprichii	7.40	1.55	13.72	9.60	17.42	10.46
Coscinospira sp. 1	0.77	0.00	0.00	0.00	0.00	0.00
Cribononion cf. *C. hawkesburiensis*	0.51	0.00	0.00	0.00	0.00	0.00
Cycloforina carinata	0.00	0.00	0.00	0.00	0.00	0.42
Cycloforina quinquecarinata	0.00	2.80	0.00	0.00	0.00	0.00
Cymbaloporetta bradyi sp. 1	0.00	0.00	0.00	0.20	0.00	0.00
Elphidium advenum	1.28	14.29	10.03	7.80	7.47	15.90
Elphidium gerthi	0.77	4.04	2.90	5.00	1.58	0.00
Elphidium jenseni	0.00	0.00	0.79	0.80	0.45	0.00
Elphidium macelliforme	0.51	0.00	0.00	0.00	0.00	0.00
*Elphidium maorium_*	0.00	0.00	0.00	0.20	0.00	0.84
Elphidium tongaense	0.00	0.00	0.00	3.60	0.00	0.00
Glabratella sp. 1	0.00	0.00	0.00	0.00	0.45	0.00
Glabratellina sp. 1	0.00	0.00	0.00	0.20	0.00	0.00
Lachlanella corrugata	0.77	2.17	0.00	1.80	0.00	0.00
Lachlanella subpolygona	0.26	0.62	0.00	0.00	0.00	0.00
Miliolinella cf. *M. circularis*	0.51	0.31	0.00	0.00	0.00	0.00
Miliolinella cf. *M. hybrida*	0.26	0.00	0.00	0.40	0.00	0.00
Miliolinella cf. *M. hybrida* sp. 1	0.00	0.31	0.79	0.40	0.00	0.84
Miliolinella cf. *M. hybrida* sp. 2	0.26	0.31	0.00	0.00	0.00	0.00
Miliolinella cf. *M. hybrida* sp. 3	0.00	0.00	0.00	0.40	0.00	0.00
Miliolinella cf. *M. hybrida* sp. 4	0.00	0.31	0.26	0.00	0.00	0.00
Miliolinella fusca	0.26	0.00	0.00	0.00	0.00	0.00
Miliolinella sp. 1	0.77	0.62	1.85	0.00	1.13	2.09
Miliolinella sp. 2	5.87	1.86	0.53	0.00	0.90	1.67

Miliolinella sp. 3	1.53	2.48	0.53	0.00	0.00	0.00
Miliolinella sp. 4	6.12	0.00	0.00	0.00	0.00	0.00
Peneroplis arietinus	4.08	0.00	1.58	1.20	5.20	1.67
Peneroplis pertusus	13.52	13.98	15.83	21.2	19.23	34.31
Peneroplis planatus	9.69	0.31	2.64	0.60	6.11	0.42
Pseudotriloculina sp. 1	0.77	2.17	4.49	0.60	2.49	0.00
Pseudotriloculina subgranulata	1.79	2.17	1.32	1.00	2.94	0.00
Quinqueloculina arenata	0.00	0.00	0.00	0.20	0.00	0.00
Quinqueloculina bidentata	0.51	0.00	0.00	0.00	0.00	0.00
Quinqueloculina carinatastriata	0.00	1.24	4.22	2.40	2.71	0.00
Quinqueloculina cf *Q. distorqueata*	0.00	0.00	0.00	0.00	0.23	0.00
Quinqueloculina eburnea	0.00	0.00	0.00	0.00	0.00	0.00
Quinqueloculina lamarckiana	3.06	0.00	2.11	0.00	0.23	0.00
Quinqueloculina myagmarsuren	0.26	0.00	0.00	0.00	0.00	0.00
Quinqueloculina seminulum	0.00	3.42	1.85	3.60	3.17	0.00
Quinqueloculina sp. 1	0.00	0.00	0.00	0.00	0.23	0.42
Quinqueloculina sp. 2	1.79	2.17	2.37	1.00	0.00	0.42
Quinqueloculina sp. 3	0.51	0.62	0.00	0.00	0.00	0.42
Quinqueloculina sp. 4	0.51	0.00	0.00	0.00	0.00	0.42
Quinqueloculina sp. 5	0.51	0.00	1.06	0.00	0.00	0.42
Quinqueloculina sp. 6	0.26	0.00	0.00	0.00	0.00	0.42
Quinqueloculina sp. 7	0.26	0.00	0.00	0.00	0.00	0.00
Quinqueloculina sp. 8	0.00	0.00	0.00	0.00	0.00	0.42
Quinqueloculina sp. 9	0.00	0.00	1.06	0.00	0.00	0.42
Quinqueloculina sp. 10	0.00	0.93	0.00	0.40	0.00	0.00
Quinqueloculina sp. 11	0.00	0.00	0.00	1.00	0.23	0.00
Quinqueloculina sp. 12	0.00	0.00	0.00	0.00	0.45	0.00
Quinqueloculina sp. 13	0.00	0.00	0.00	0.00	1.36	0.00
Quinqueloculina sp. 14	0.51	0.00	1.06	1.20	2.04	0.00
Quinqueloculina sp. 15	0.00	0.00	1.32	0.20	3.17	0.00
Quinqueloculina sp. 16	0.00	0.00	2.37	0.00	0.00	0.00
Quinqueloculina sp. 17	0.26	0.00	0.00	0.00	0.00	0.00
Quinqueloculina sp. 18	0.00	1.24	0.53	0.20	0.00	0.00
Quinqueloculina sp. 19	0.00	0.00	0.00	0.20	0.00	0.00
Quinqueloculina sp. 20	1.28	0.00	0.00	0.00	0.00	0.00
Quinqueloculina sp. 21	1.02	0.00	0.00	0.00	0.00	0.00
Quinqueloculina sp. 22	0.51	0.00	0.53	0.00	0.00	0.00
Quinqueloculina sp. 23	1.53	0.62	0.26	2.00	0.00	0.00
Quinqueloculina subgranulata	1.53	0.00	0.00	0.00	0.00	0.00
Quinqueloculina timorensis	0.00	0.00	0.79	0.00	0.00	0.00
Rosalina bradyi	0.00	0.00	0.00	0.20	0.00	0.00
Sorites orbicularis	0.26	0.31	0.00	0.00	0.68	0.00

Spiroloculina aff. *S. indica*	0.00	0.00	0.00	0.20	0.00	0.00
Spiroloculina attenuata	0.51	0.00	0.00	0.80	0.00	0.00
Spiroloculina cf. *S. nummiformis sp. 1*	0.26	0.00	0.00	0.00	0.00	0.00
Spiroloculina cf. *S. nummiformis sp. 2*	1.02	0.00	0.26	0.00	0.00	0.00
Spiroloculina communis	0.26	0.00	0.00	0.00	0.00	0.00
Spiroloculina excavata	0.51	0.00	0.00	0.00	0.00	0.00
Spiroloculina hadai	0.77	0.00	0.00	0.40	0.00	0.00
Spiroloculina indica	2.81	0.93	1.06	0.00	0.00	0.42
Spiroloculina pulchella	0.26	0.00	0.00	0.00	0.00	0.00
Spiroloculina rotundata	0.26	0.31	0.00	0.00	0.00	0.84
Spiroloculina sp. 1	0.26	0.00	0.00	0.00	0.00	0.00
Spiroloculina sp. 2	0.00	0.00	0.00	0.20	0.00	0.42
Spiroloculina sp. 3	0.26	0.00	0.00	0.00	0.00	0.00
Spiroloculina sp. 4	0.00	0.00	0.00	0.00	0.90	0.00
Spiroloculina sp. 5	0.00	0.00	0.00	0.00	0.23	0.00
Spiroloculina sp. 6	0.00	0.00	0.00	0.20	0.00	0.00
Spiroloculina sp. 7	0.00	0.00	0.00	0.20	0.00	0.00
Spiroloculina sp. 8	0.00	0.00	0.00	0.20	0.00	0.00
Spiroloculina sp. 9	0.26	0.00	0.00	0.00	0.00	0.00
Spiroloculina sp. 10	0.26	0.00	0.00	0.00	0.00	0.84
Triloculina cf. *T. serrulata* sp. 1	0.51	0.00	0.26	0.00	0.00	0.00
Triloculina cf. *T. serrulata* sp. 2	0.26	0.00	0.26	0.00	0.00	0.00
Triloculina cf. *T. serrulata* sp. 3	0.00	0.00	0.26	0.00	0.00	0.00
Triloculina cf. *T. serrulata* sp. 4	0.00	0.00	0.00	0.20	0.00	0.00
Triloculina aff. *T. vespertilio*	0.00	0.93	0.00	0.20	0.00	0.00
Triloculina cf. *T. tricarinata*	0.26	0.31	0.00	0.00	0.00	0.00
Triloculina cf. *T. affinis*	0.00	0.00	0.00	0.20	0.00	0.00
Triloculina cf. *T. asymmentrica*	0.00	2.48	0.00	0.00	1.13	4.60
Triloculina cf. *T. fichteliana* sp. 1	0.26	1.24	0.00	0.00	0.00	0.00
Triloculina cf. *T. fichteliana* sp. 2	0.00	0.00	0.53	0.00	0.00	0.00
Triloculina cf. *T. fichteliana* sp. 3	0.00	0.00	0.00	0.00	0.68	0.00
Triloculina cf. *T. vespertilio*	0.00	0.00	0.00	1.00	0.00	0.00
Triloculina marioni	0.77	0.00	0.00	0.00	0.00	0.00
Triloculina plicata	0.26	0.00	0.00	0.00	0.00	0.00
Triloculina sp. 1	0.00	0.00	0.00	0.00	0.00	2.51
Triloculina sp. 2	0.00	0.00	0.00	0.40	0.00	0.00
Triloculina sp. 3	0.00	0.00	0.00	0.20	0.00	0.00
Triloculina sp. 4	0.26	0.00	0.00	0.00	0.00	0.00
Triloculina trigonula	1.53	1.86	1.32	0.00	1.36	2.09
Trochammina inflata	0.00	0.00	0.00	0.00	0.45	0.00
Vertebralina striata	0.26	0.31	1.32	0.80	0.00	0.84

7.3 Results

The results of the study are presented in a format in line with the only previous study of lagoonal foraminifera in the Arabian Gulf (Murray, 1970a). Our observations and subsequent discussion are based on total foraminiferal assemblage composition. However, for future reference, percentages of living forms encountered, and the abundance of juveniles of *Quinqueloculina*, *Triloculina* and *Miliolinella* that are too difficult to identify, are also documented (Table 6). Over 3500 specimens were picked, 39% living (Rose Bengal stained) and 61% dead benthic foraminiferal tests. A total of 120 benthic foraminiferal species were identified, belonging to 24 genera (Figure 34), 61 of which were identified to the genus level but left in open nomenclature due to the lack of detailed taxonomic studies for the Arabian Gulf region. This approach allows for the assessment of diversity within the lagoon and documentation for future taxonomic work. Within the lagoon, the benthic foraminiferal density calculated from the total assemblage (206 specimens/20 cm^3) is highest on the algal mat subenvironment; this station is adjacent to the inlet channel. The lowest density (56 specimens/20 cm^3) was recorded within the backback pool (Table 6). All the samples analysed contained 30 or more species with an average of 42. The maximum diversity (64 species) was found in the sheltered inner lagoon, and the minimum diversity (30 species) was observed in the back pool. The most common species across all the subenvironments are *Peneroplis pertusus*, *Ammonia convexa*, *Coscinospira hemprichii*, and *Elphidium advenum* (Figure 34). Faunal analysis based on relative abundances of species in the six shallow-water subenvironments reveals two main assemblages of benthic foraminifera: an *Ammonia convexa–Elphidium advenum–Peneroplis pertusus* assemblage, and an *Ammonia convexa–Coscinospira hemprichii–Peneroplis pertusus* assemblage. Representative specimens of dominant, rare and epiphytic species are illustrated in in Figure 35–38. The full faunal list is given in Table 7.

7.3.1 Sheltered Inner Lagoon

This subenvironment constitutes the lagoon interior and is sheltered from rapid tidal changes and direct influence of marine water replenishment. It has the highest number of foraminiferal species compared to all the other subenvironments. Four species, *Ammonia convexa*, *Peneroplis pertusus*, *Peneroplis planatus*, and *Coscinospira hemprichii*, account for 52% of the abundance, and the dominant species is *Ammonia convexa*. Out of 64 species identified within this subenvironment, 45 have relative abundances less than 1%.

7.3.2 Algal Mat

Filamentous mucilaginous greenish algal mat cover characterizes the algal mat subenvironment sediment. The sediment has a pungent hydrogen sulphide smell and exposed patches of sediments are covered by thin veneer of dark oxidized sediment. Five species comprise 62% of the fauna: *Ammonia convexa*, *Elphidium advenum*, *Peneroplis pertusus*, *Ammonia tepida*, and *Elphidium gerthi*. Out of 37 species identified within this subenvironment, 18 have relative abundances less than 1%.

7.3.3 Tidal Channel

The tidal channel is floored with biogenic sediments and appears to vary in size as it empties into the lagoon proper, narrow at the entrance and flattens out into the lagoon interior. The ratio of live/dead (0.91) specimens is highest in the tidal channel, as is the second highest percentage of miliolid juveniles. *Peneroplis pertusus* (16%) dominates this subenvironment, while five species account for 63% of the total abundance *Ammonia convexa*, *Peneroplis pertusus*, *Coscinospira hemprichii*, *Elphidium advenum*, *Pseudotriloculina* sp. 1 and *Quinqueloculina carinatastriata*

7.3.4 Tidal Flat

The tidal flat is the immediate adjacent subenvironment to the tidal channel and appears to be the most affected by tidal changes. Completely submerged at high tide and at other times appearing only wet when the water level falls to depth within the channel. The tidal flat is dominated by *Peneroplis pertusus* (21%), which can be easily identified in the field as a whitish component of the otherwise dark sediment. Five species account for 70% of the total abundance of this subenvironment including *Ammonia convexa*, *Coscinospira hemprichii*, *Elphidium advenum*, *Ammonia tepida*, and *Elphidium gerthi*.

7.3.5 Salicornia Marsh

The sample included specimens that were directly shaken off *Salicornia* plant roots and the sediment directly under the plants. The dominant species in this subenvironment was *Peneroplis pertusus*. Four species accounted for over 56% of the relative abundance including *Peneroplis pertusus, Coscinospira hemprichii*, *Ammonia convexa* and *Elphidium advenum*. Fifteen of the 33 identified species in this subenvironment had abundances less than 1%.

7.3.6 Back Pool

The back pool subenvironment comprises small patches of water ponding devoid of any vegetation and lies between patches of *Salicornia* marsh that frequently dries out during the summer. *Peneroplis pertusus*, *Elphidium advenum* and *Ammonia convexa* constitute 62% of the foraminiferal assemblage and 18 of the 30 identified species have relative abundances less than 1%. *Peneroplis pertusus* (34%) is the dominant species.

7.3.7 Ternary Plot

The distribution of agglutinated, porcelaneous and hyaline taxa is summarized in the ternary plot below for all the sampling stations (Figure 39) and compared with previously described hypersaline lagoonal assemblages in the United Arab Emirates by Murray (1970a). Ternary plots became a standard after the work of Murray (1970a), they are used to compare and contrast the contribution of taxa based on porcelaneous, agglutinated and hyaline wall types. Plots of this nature are used to infer the dominant salinity regime in an area.

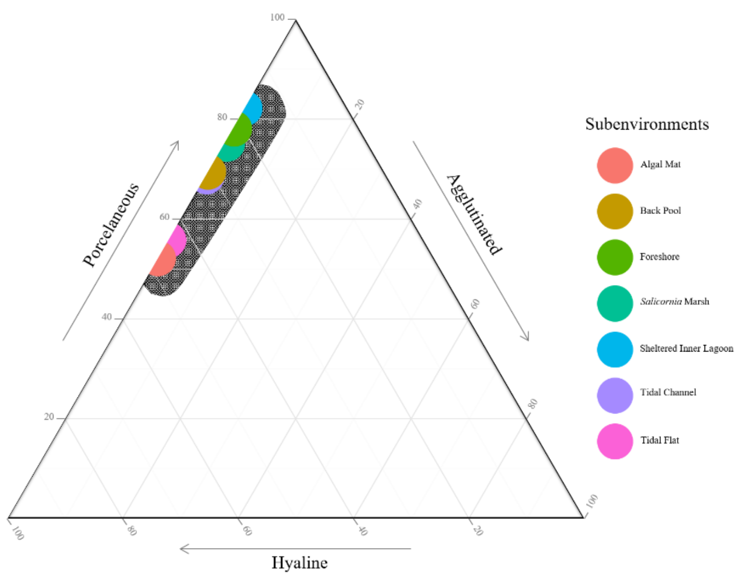

Figure 26. Ternary plot based on wall texture groupings. Shaded area indicates hypersaline lagoon assemblages from Murray (1970a)

7.4 Discussion

The results of our survey agree well with studies of other hypersaline lagoons studies in terms of the proportions of major wall-texture groups (Figure 39). However, the foraminiferal diversity of the hypersaline Murray's Pool (lagoon) is unusually high and exceeded our expectations based on earlier studies of benthic foraminifera in the Gulf region. Cherif et al. (1997) previously assigned the territorial waters of Bahrain to his low-diversity "southern Arabian Gulf biofacies", in which he reported only 72 species. We observe nearly twice this number in a single lagoon. Cherif et al. (1997) identified only 98 species from the entire Gulf, covering a wide range of environments. We believe the number of species is too low considering the size of area and the range of environments. Comparing to the number of species (337 including planktonic foraminifera) in the Gulf of Aqaba identified by Hottinger et al. (1993), Cherif's number appears to be very low. Cherif likely used wider taxonomic concepts, and our estimate probably better reflects the actual diversity. The species diversity increases towards the lagoon's interior with the sheltered inner lagoon harbouring the most diverse assemblage. Physical processes and characteristics of the subenvironment such as shelter can explain this high diversity. The inner lagoon is protected from direct impact of waves, from drying out all year round, and there are negligible tidal changes within the pool. Advances in foraminiferal taxonomy is likely the most important factor contributing to the higher diversity reported, although avian transport may contribute to diversity at this locality.

The ternary plot for Murray's Pool falls within the field of hypersaline assemblages and is dominated by porcelaneous and hyaline forms (Figure 39), which are characteristic of a hypersaline lagoonal environment in agreement with Murray's (1970a, 1991) observations. The assemblages are able to withstand extremes of salinity, temperature, and sediment substrate typical of hypersaline environments in the Arabian Gulf (Murray, 2006; Riegl et al., 2010). *Peneroplis pertusus* is the most abundant living/dead species in the lagoonal sample and together with *Peneroplis planatus* and species of *Miliolinella*, *Quinqueloculina, Triloculina, Elphidium,* and *Ammonia* form the most widespread hypersaline lagoonal assemblage. The distribution of peneroplids correlates with the presence of vegetation both within and outside the lagoon. They live primarily as epiphytes on seaweeds and on seagrass (Murray 1970a, 2006). The dominance of calcareous porcelaneous forms might suggest a higher degree of confinement and in turn restricted conditions (Frontalini et al., 2011).

Distributions of living foraminifera in the different subenvironments are highly variable. The highest numbers of living foraminifera are found in tidal flat and tidal channel while lowest numbers were recorded at the back pool subenvironment. The high abundance of foraminifera in the tidal flat and channel can be attributed to daily tidal currents that nourish and drain the lagoon bringing in juveniles, nutrients, and well-oxygenated water. The current may also bring in juveniles, which might later establish themselves within the pool. The lagoon generally has viable species adapted to high salinity and other fluctuating environmental parameters.

Several species identified to genus level in this study appear to be new to science. *Quinqueloculina carinatastriata* (Wiesner, 1923) is reported for the first time in the Arabian Gulf from samples collected from the tidal channel, tidal flat, *Salicornia* marsh, and algal mat in relatively large numbers. The species is conspicuously missing from the sheltered inner lagoon and back pool, which might provide insight to its ecological requirements due to characteristics of these subenvironments. The species was previously described from the Mediterranean and the Red Sea. Although the species is known from tropical and subtropical region, Bouchet et al. (2007) is of the opinion that the species has extended its ecological range mainly through the mariculture trade and/or shipping activities. This is plausible, as Murray's Pool is next to Bahrain's Department of Mariculture and the area is renowned for shipping activities.

7.5 Conclusions

This study provides baseline biodiversity data for future environmental impact studies in the western Arabian Gulf area lagoons. Our aim is to contribute to the understanding of the foraminiferal diversity in paralic environments and establish a reference point for assessing the environmental impact of rapid developmental projects in the Arabian Gulf.

The Askar locality has changed drastically from when we first sampled the area, confirming our fears that the lagoon may soon disappear under a recreational facility. Figure 33A summarizes some of the changes. From June 2010 to April 2015, the southeastern part of Askar village witnessed rapid development in the form of construction of a jetty, expansion of roads and car parks, housing projects, installation of a drainage network, and expansion of the seaside park and marine mariculture station. Some of these activities have led to an estimated loss of over 50% of shallow marine habitats within the area of Murray's Pool owing to land reclamation, and invariably, the loss of foraminiferal habitat. These developments show no signs of abating and there are strong indications that additional shallow marine habitats in the area will be reclaimed soon.

Our main finding is that previous studies in the Arabian Gulf have seriously underestimated the diversity of foraminifera in the region. Basson and Murray (1995) conducted a temporal study by monitoring only four foraminiferal taxa in the lagoon, whereas our study documents the total assemblage. The total number of species recorded at this one locality (120) is high in comparison with earlier foraminiferal studies of the region, such as 72 species in the "southern Arabian Gulf biofacies" reported by Cherif et al. (1997). The dominant taxa in our study are similar to those reported from a lagoon in the United Arab Emirates by Murray (1970a), but the percentage of living foraminifera is higher in our study compared to Murray's findings, which might be due to differences in (a) sampling period; our sampling coincides with the blooming period in winter (2014) when juveniles are abundant (Arslan et al., 2016); (b) the nature of the sampled environment; Murray's Pool is very shallow, the deepest part in mid channel is about 40 cm; (c) greater taxonomical effort in identifying these marine organisms; and (d) differences in temperature and salinity which may be extreme in summer. Several species appear to be endemic to the area and are probably new to science. The findings of this study can serve as a modern analogue for ancient lagoonal sediments of the Cenozoic petroleum reservoirs of offshore Saudi Arabia (Al-Saad and Ibrahim, 2002; Chan, 2016).

Bearing in mind the continued degradation of shallow marine environments in Bahrain and neighbouring countries through seafront land reclamation, our findings imply that some endemic species will never be known because these habitats will irreplaceably disappear. Our current effort might be the last documentation of this locality owing to the noticeable pace of development in the area.

CHAPTER 8

Distribution of benthic foraminifera along the Iranian Coast

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SUMMARY-- This study focuses on the distribution of benthic foraminifera along the Iranian coast of the Gulf from the northeast close to Shatt Al-Arab/Arvand Rud to the southeast near the Strait of Hormuz where it connects to the Indian Ocean. The Gulf is a naturally stressed environment due to extremes of salinity, temperatures and anthropogenic influences such as rapid urbanization projects, maritime transport, large numbers of desalination plants and oil platforms. These activities over time continue to compound the already stressed environment. Historical records on foraminiferal diversity and distribution in the Gulf commonly have underestimated its benthic foraminiferal composition and diversity. Thirty-two samples collected from depths of 20–45 m were analyzed for total foraminiferal assemblages. A total of 224 benthic foraminiferal species and subspecies belonging to 63 genera, 34 families, 22 superfamilies and six orders were recognized. The assemblages are dominated by hyaline (45.3%) and porcelaneous (35.3%) taxa, while agglutinated foraminiferal groups comprise a lower proportion (19.4%). The ten most abundant genera include *Asterorotalia* (13.3%), *Quinqueloculina* (12.4%), *Bolivina* (9.8%), *Nonion* (8.6%), *Ammonia* (5.5%), *Textularia* (5.4%), *Elphidium* (5.2%), *Cibicides* (3.9%), *Challengerella* (3.6%) and *Hanzawaia* (3.4%). The most common species are *Nonion* sp. 1 (5.45%), *Asterorotalia dentata* (5.03%), *Quinqueloculina* sp. 1 (4.8%), *Nonion* sp. 2 (4.5%), *Rotalinoides* cf. *R. gaimardii* (3.3%), *Asterorotalia* sp. 3 (3.2%), *Quinqueloculina* sp. 8 (3.1%), *Bolivina* cf. *B. persiensis* (3.0%), *Bolivina* cf. *B. striatula* (2.9%), and *Ammonia* sp. 1 (2.9%). We speculate that feeding strategy, e.g., herbivore (*Nonion, Ammonia, Elphidium and Asterorotalia*), increase of finer sediments (mud), availability of nutrients and presence of oxygen are factors controlling the diversity and distribution of benthic foraminifera in the Gulf. Due to the importance of this water body in a changing world climate, this study updates the knowledge on the type and distribution of benthic foraminiferal groups.

8.1 Introduction

The usage of "Arabian" or "Persian" Gulf to refer to the water body enclosed between Iran and the Arabian Peninsula remains to this day a very sensitive and contentious issue (Sheppard et al., 1992). In line with current wider usage in scientific studies that provide historical records of benthic foraminifera and other microbenthos in the area, this water body will simply be referred to as "the Gulf" throughout this study. The Gulf is very important for both scientific and economic reasons due to its shallow depth, position within the great desert belt, and crude oil wealth. The Gulf is also known to be the most extensive stretch of hypersaline shelf on earth and unique for its endemic flora and fauna that have adapted to extremes of salinity and temperature (Murray, 1991; Naser, 2011b). Additionally, the area witnesses a high volume of maritime activities due to its oil and gas deposits. In a world experiencing climate change, the prevailing thermal regime in the Gulf has been cited as a model for the tropical ocean in 2090–2099 (Solomon et al., 2007; Riegl and Purkis, 2012).

8.1.1 Geography and Geological Setting

The Gulf is a quaternary shallow tectonic depression, a result of the Zagros Orogeny, created by collision and compression between the Arabian and Asian plates. It is a marginal sea extension of the Indian Ocean, and covers an area of approximately 22,600 km^2 (Kassler, 1973; Seibold et al., 1973). It is elongated along its axis trending NW–SE; measures 1000 km in length, 300 km at its widest point, and 60 km where it is constricted by the Strait of Hormuz where it opens into the Indian Ocean (Purser, 1973; Murray, 1991).

The morphology of the Gulf is influenced by the interaction of the Arabian platform and Zagros folds, i.e., a relatively stable Arabian foreland flanking the Precambrian Arabian shield and subsiding below the unstable Zagros fold belt area (Kassler, 1973; Purser and Seibold, 1973). Compared to the rocky, mountainous terrain of the Iranian coast, the Arabian marine shelf is gentler, wider, and largely produced by salt diapirism or erosional relicts of the Quaternary (Kassler, 1973). The presence of the Qatar Peninsula, however, modifies the rather uniform Arabian coastline by changing the pattern of sedimentation and current movement in the southeastern sectors of the Gulf (Riegl and Purkis, 2012). The aforementioned shoreline is also characterized by sabkhas (evaporitic flats), supratidal areas, and extensive storm beaches in more exposed settings (Kassler, 1973; Purser and Evans, 1973; Purser and Seibold, 1973).

The Gulf can be divided into two sedimentary realms based on predominant sediment types; autochthonous pure carbonate with siliciclastic admixture dominating the southern Arabian realm, and the northern fluvial Iranian realm (Riegl et al., 2010). The sea floor of the Gulf is gently inclined towards the shelf break with an average depth of 35 m and maximum depth of 100 m at the Strait of Hormuz. The Gulf is arguably a classical example of a mixed carbonate–siliciclastic ramp system (Riegl et al., 2010).

The submarine topography of the Gulf, which predominantly has a very gentle sea-floor gradient and several bathymetric highs (especially in the south), also reflects the interaction of the Arabian Peninsula and Zagros mountains (Purser, 1973). Coupled with salt diapirism, the Gulf has >20 islands and several bathymetric highs (Kassler, 1973). The deeply submerged highs are important areas of foraminiferal sand accumulation particularly towards the basin axis (Riegl and Purkis, 2012). Depending on their origin, i.e., due to the Zagros orogeny or salt tectonics by the Hormuz salt, the bathymetric highs can be classified as coastal or basin central types (Purser, 1973; Riegl and Purkis, 2012).

Kassler (1973) noted that sediment type in an area is controlled by its biological communities, while the submarine topography dictates the sediment thickness. Sparker records show that sediment thickness is least on topographic highs, and greatest in depressions (Purser, 1973). The Shatt Al-Arab river delta forming the northwest shoreline and many rivers along the Zagros mountain area in coastal Iran forming the eastern flank, deliver significant amounts of terrigenous sediment and greatly influence the sedimentology of the Gulf (Purser and Seibold, 1973a; Alsharhan and Kendall, 2003). Several rivers originating from the Zagros mountain area run into the Gulf and are characterized by frequent "flash-floods”. Notable among these rivers are Arvand Rud (Shatt Al-Arab), Gamasb, Karun, Jarahi, Zohreh, Dalaki, Mend, Shur, Minab, Mehran and Naband (Figure 40). Rivers discharge mud and fine sand, consequently the sediment off the Iranian coast is dominated by marl, and the carbonate content increases away from this coast (Seibold et al., 1973). Many of the sedimentary parameters in the eastern sector of the Gulf can be directly linked to the Iranian river mouths (Kassler, 1973; Purser and Seibold, 1973).

The Gulf is situated in an arid, subtropical climate region experiencing extremes of summer temperature and salinity due to its enclosed nature. The range for water temperatures in offshore areas of the Gulf are 20–32°C (Clarke and Keij, 1973), western gulf is 16–36°C (John et al., 1990), while in lagoonal areas the range is 15–40°C (Purser and Seibold, 1973; Joydas et al., 2015). The tides are complex, and range from diurnal, semi-diurnal to mixed (Riegl et al., 2010). Wind direction is mostly northwesterly caused by the seasonal Shamal “north” wind throughout the year. Wind is an important physical factor; it accounts for an appreciable amount of aeolian siliciclastic sediment input into the Gulf (Riegl et al., 2010). Due to the shallow nature of the Gulf, almost all parts are within the photic zone with few exceptions along the Iranian Coast (Murray, 2006).

Rainfall is scare (3–8 cm/y) while evaporation rates (140–500 cm/y) are high and associated with the prevalent high temperatures, strong winds, and low precipitation (Reynolds, 1993). Salinity is marked by a seasonal gradient both horizontally and vertically largely due to the absence of much oceanic buffering (Reynolds, 1993). The Gulf can be also split into two realms, based solely on surface water salinity differences: a northern, less saline realm and a southern more saline realm owing to inflowing surface waters from the Arabian Sea through the Straits of Hormuz that have a salinity of about 36.5‰. This value increases rapidly to about 40‰ in mid Gulf and reduces to about 36.5‰ at the Shatt Al-Arab due to dilution from freshwater input (Riegl et al., 2010; Sheppard et al., 2010, 1992). There is also a marked west to east gradient along the Gulf axis, with the Arabian side becoming more saline. In some lagoons and embayments southeast of Qatar, salinity can exceed 50‰ (Murray, 1970a), while in Half-Moon Bay on the Saudi coastline we have measured salinity in excess of 60‰.

8.1.2 Previous foraminiferal studies in the Gulf

There have been relatively few distributional, taxonomical or ecological studies of foraminifera in the Gulf. Most studies are localized and asymmetrical, with the southwestern (Murray, 1965a, 1965b, 1966a, 1966b, 1966c, 1970a, 1970b; Ahmed, 1991; Basson and Murray, 1995; Hitmi and Hitmi, 2000; Parker and Gischler, 2015; Amao et al., 2016b) and northern (Al-Zamel and Cherif, 1998; Al-Zamel et al., 2009, 1996) sectors receiving more attention. The eastern part, which stretches along the entire coast of Iran, is poorly known (Haake, 1970; Lutze, 1974d; Haake, 1975).

Cherif et al. (1997) reported 94 benthic foraminiferal species for the entire Gulf covering a wide range of environments. Compared to the number benthic foraminiferal species (350) in the Gulf of Aqaba (an extension of the Red sea) identified by Hottinger et al. (1993) and 1000 species in the Mediterranean Sea (Frontalini et al., 2015), Cherif's number appears to be quite low. The benthic foraminiferal species identified by Cherif et al. (1997) are represented by 53 genera, 30 families, 18 superfamilies and five orders dominated by three rotaliid species *Ammonia* cf. *aberdoveyensis* (9.7%), *Challengerella bradyi* (9.3%) and *Asterorotalia dentata* (8.9%).

Recent studies on a carbonate ramp off the coast of Kuwait by Parker and Gischler (2015) document the presence of 141 species belonging to 51 genera, 27 families, 19 superfamilies and four orders. The authors reported five assemblages varying from shallowest to deepest areas: *Peneroplis–Elphidium crispum*, Miliolid, Miliolid–*Elphidium*, *Elphidium–Nonion*, *Asterorotalia–Elphidium* (i.e., there is an onshore–offshore pattern).

In a restricted lagoon in Bahrain, Amao et al. (in press) identified 136 species, 25 genera, 15 families, 10 superfamilies and four orders. The lagoonal species were dominated by *Peneroplis pertusus*, *Ammonia convexa*, *Coscinospira hemprichii*, and *Elphidium advenum*. These new findings probably better reflect the real diversity of the western Gulf. In recent studies of modern foraminiferal faunas in the Gulf, many species have been reported in open nomenclature or are only tentatively identified (Cherif et al., 1997; Parker and Gischler, 2015; Amao et al., 2016b). Much more taxonomical effort needs to be invested in the Gulf faunas before we can reliably estimate their biodiversity. As such, the objectives of this study along the Iranian sector of the Gulf are to (i) document benthic foraminiferal species and their distribution along over 1000-km-long sampled coastline, (ii) analyze the spatial distribution of foraminiferal assemblages, and (iii) determine environmental factors that might control the distribution and species richness of benthic foraminiferal assemblages. Such studies will enhance our understanding of environments and provide a baseline for future studies in the Gulf.

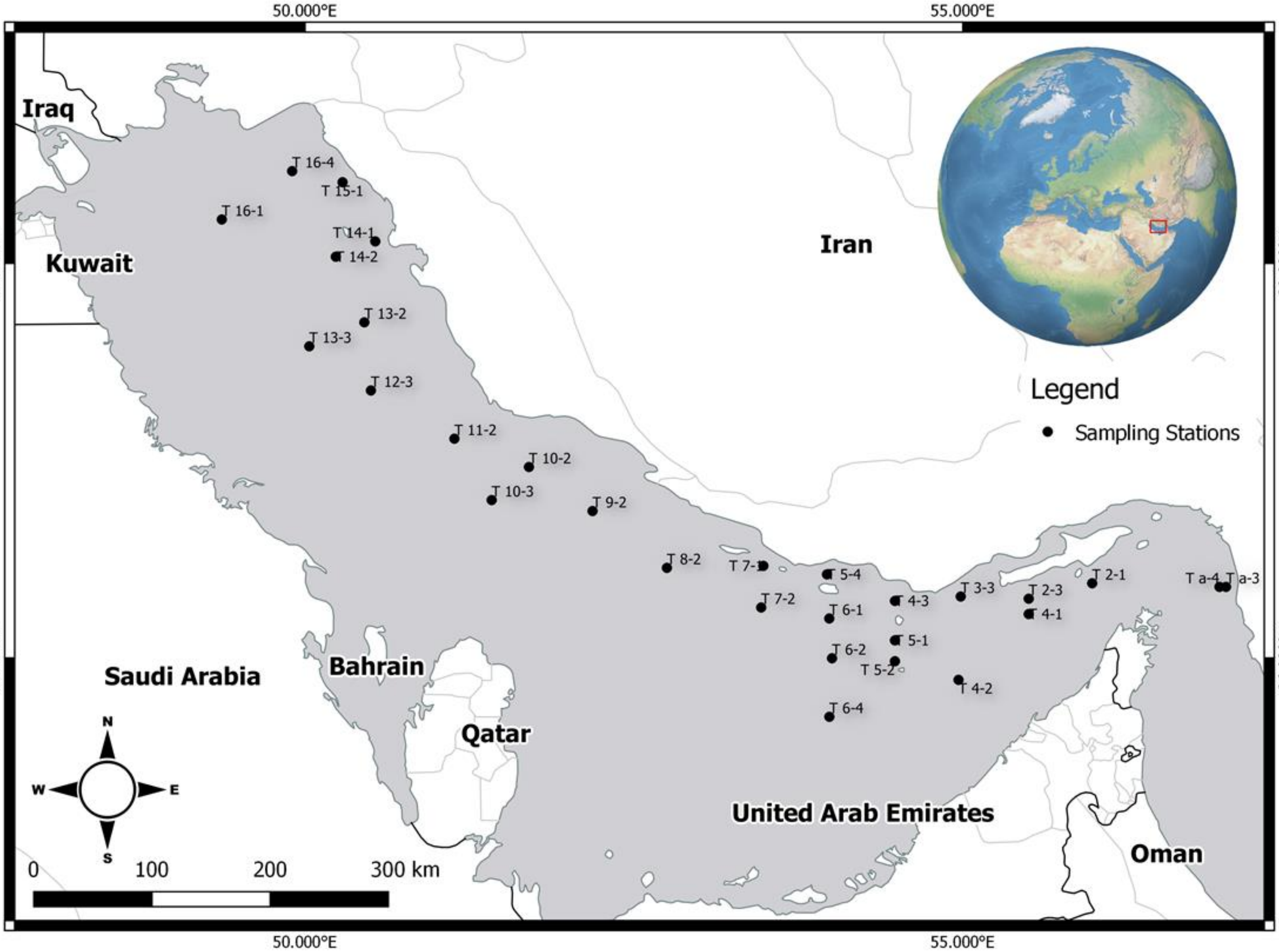

Figure 27. Sampling area map with region overview map showing extent of the Gulf and bordering countries

8.2 Methodology

8.2.1 Sampling

Thirty-two samples were collected along the Iranian coast of the Gulf from the northeast close to Shatt Al-Arab/Arvand Rud to the southeast near the Strait of Hormuz (Figure 40) using a Van Veen grab (0.1 m^2 area). Sediment samples for benthic foraminiferal study were stored in 100 ml sampling bottles. In the laboratory, samples were wet-sieved through a 63 µm mesh sieve, dried, and later split into equal aliquots using a micro-splitter to generate subsamples with approximately 300 benthic foraminiferal tests (total assemblage). Specimens were picked quantitatively from the 63 µm fraction. Recognized taxa were illustrated using scanning electron microscopy (SEM) (JEOL JSM-5900LV) at the Geosciences Department, King Fahd University of Petroleum & Minerals in Dhahran (Saudi Arabia).

8.2.2 Statistical Analyses

The relative abundances of taxa, Fisher-α, Dominance (D), Shannon-Weaver (H), and equitability (E) indices were calculated for each sampling station, and the foraminiferal relative abundances were standardized prior to multivariate analysis by expressing counts of individual taxa as a percentage of the total for each station where they were found. Statistical analyses included data transformation, spatial distribution plot, polygons, cluster analysis (CA) using Ward Method of agglomeration and Euclidean distances, and principle component analysis (PCA) using the singular value decomposition method. Data sub-setting were carried out using R (R Core Team, 2016) by the following packages ggplot2 (Wickham, 2009), tidyr (Wickham, 2016), dplyr (Wickham and Francois, 2015), ggmap (Kahle and Wickham, 2013), rgdal (Bivand et al., 2016), rgeos (Bivand and Rundel, 2016), factoextra (Kassambara and Mundt, 2016), FactoMineR (Lê et al., 2008), cluster (Maechler et al., 2016) and ggtern (Hamilton, 2016). Calculation of diversity indices was performed in PAST v1.97 (Hammer et al., 2001). The sampling map was generated using QGIS (QGIS, 2016), while taxa distribution maps were created using Surfer® 13 (Golden Software, LLC). Station T2-3 was excluded from the multivariate analysis because it yeilded a low number of individuals (50). Genera with a relative abundance <5% were also excluded from the multivariate analysis, following recommendations by (Hayek and Buzas, 2013).

8.2.3 Taxonomy and systematics

Identification of foraminifera in this study was based on the works of Zheng (1988), Hottinger et al. (1993), Albani and Yassini (1993), Cherif et al. (1997), Hayward et al. (1997, 1999), (Parker, 2009), and Debenay (2012). When these references proved insufficient, the classic monographs of McCulloch (1977) and Loeblich and Tappan (1994) were consulted for generic level identification. Although no comprehensive taxonomic guide to the Foraminifera of the Gulf region yet exists, one of the objectives of this study is to make a taxonomic reference collection of Gulf Foraminifera. The faunal reference microslides are currently housed in the author's collection at KFUPM. These will be permanently archived in the European Micropaleontological Reference Center at Micropress Europe in Kraków (Poland). World Register of Marine Species collections were used to verify the validity of taxonomic names and groups (WoRMS, 2016).

8.3 Results

8.3.1 Benthic Foraminifera

A total of 224 benthic foraminiferal species and subspecies were identified belonging to 63 genera, 34 families, 22 superfamilies and six orders (Table 8). Based on the entire counted samples, the benthic foraminiferal were grouped based on wall types, i.e., hyaline (45.3%), porcelaneous taxa (35.3%) and agglutinated foraminiferal groups are also fairly represented (19.4%) and the result summarized in Figure 41. The ten most abundant genera are *Asterorotalia* (13.3%), *Quinqueloculina* (12.4%), *Bolivina* (9.8%), *Nonion* (8.7%), *Ammonia* (5.5%), *Textularia* (5.4 %), *Elphidium* (5.2%), *Cibicides* (3.9%), *Challengerella* (3.6%) and *Hanzawaia* (3.4%). Genera with a relative abundance lower than 0.02% include *Spiroplectinella*, *Falsagglutinella*, *Planorbulina*, *Flintina*, *Siphouvigerina*, *Lagenammina*, *Reussella*, *Lagena* and *Oolina*. The ten most abundant species are: *Nonion* sp. 1 (5.5%), *Asterorotalia dentata* (5.0%), *Quinqueloculina* sp. 1 (4.8%), *Nonion* sp. 2 (4.5%), *Rotalinoides* cf. *R. gaimardii* (3.3%), *Asterorotalia* sp. 3 (3.2%), *Quinqueloculina* sp. 8 (3.1%), *Bolivina* cf. *B. persiensis* (3.0%), *Bolivina* cf. *B. striatula* (2.9%), and *Ammonia* sp. 1 (2.9%). The following species have above average relative abundances: *Elphidium* cf. *E. neosimplex*, *Elphidium* sp. 1, *Challengerella* sp. 1, *Spirotextularia* cf. *S. floridana*, *Bolivina* cf. *B. suezensis*, *Cibicides* sp. 1, *Cibicides* sp. 2, *Porosononion* sp. 1, *Ammonia* cf. *A. aberdoveyensis*, *Hanzawaia* sp. 1, *Asterorotalia* sp. 2, *Hanzawaia* sp. 2, *Textularia* cf. *T. foliacea*, *Siphonaperta* sp. 1, *Sigmoilopsis* sp. 1, *Spiroloculina* sp. 1, *Textularia foliacea*, *Bolivina* cf. *B. plicata*, Cycloforina quinquecarinata *Cycloforina* cf. *C. quinquecarinata* , *Spiroplectammina* sp. 1, *Challengerella cf. C. persica*, *Spiroloculina rotundata*, *Bolivinellina* cf. *B. translucens*, *Textularia pala*, *Quinqueloculina* sp. 2, *Lobatula lobatula*, *Cibicides* cf. *C. refulgens*, *Sigmoilopsis* cf. *S. herzensteini*, *Brizalina striatula*, *Amphistegina papillosa*, *Hanzawaia* sp. 3, *Textularia oceanica*, *Bulimina* sp. 1, *Asterorotalia* sp. 1, *Bulimina biserialis*, *Textularia* sp. 1, *Triloculina* sp. 1, *Cancris bubnanensis*, *Ammonia* cf. *A. faceta*, *Textularia* sp. 13, and *Cancris* cf. *C bubnanensis*. Selected taxa are illustrated (Figure 42–44) and their spatial distribution mapped out in Figure 45–46. Based on WoRMS (2016) hierarchical taxonomic groupings of foraminifera, six orders of benthic foraminifera are recognized along the Iranian coast and adjacent areas sampled (offshore). These include the following six orders: Astrorhizida, Lituolida, Textulariida, Miliolida, Lagenida, and Rotaliida.

The order **Astrorhizida** is represented by only one superfamily (Saccamminoidea), one family (Saccamminidae) and one genus (*Lagenammina*). Two superfamilies (Nodosarioidea and Polymorphinoidea), four families (Lagenidae, Nodosariidae, and Ellipsolagenidae Glandulinidae) and five genera (*Lagena*, *Pyramidulina*, *Fissurina*, *Oolina* and *Glandulina*) have been identified within the Order **Lagenida**. The order **Lituolida** is represented by four superfamilies (Lituoloidea, Rzehakinoidea, Spiroplectamminoidea and Verneuilinoidea), four families (Haplophragmoididae, Trilocularenidae, Spiroplectamminidae and Verneuilinidae) and five genera (*Haplophragmoides*, *Falsagglutinella*, *Spiroplectammina*, *Spiroplectinella*, and *Gaudryina*). Two superfamilies (Milioloidea and Nubecularioidea), four families (Cribrolinoididae, Hauerinidae, Spiroloculinidae and Nubeculariidae) and thirteen genera (*Adelosina*, *Flintina*, *Miliolinella*, *Pseudotriloculina*, *Pyrgo*, *Quinqueloculina*, *Sigmoilopsis*, *Sigmamiliolinella*, *Siphonaperta*, *Triloculina*, *Spiroloculina Nubeculina*, and *Pseudonubeculina*[2]) have been identified within the Order **Miliolida.** The order **Rotaliida** has the highest representation, twelve superfamilies

[2] The Authors couldn't establish a suitable family for this genus

(Acervulinoidea, Asterigerinoidea, Bolivinitoidea, Bolivinoidea, Buliminoidea, Chilostomelloidea, Discorboidea, Nonionoidea, Nummulitoidea, Planorbulinidea, Planorbulinoidea and Rotalioidea), twenty families (Acervulinidae, Amphisteginidae, Bolivinitidae, Bolivinitoidae, Bolivinidae, Buliminidae, Trimosinidae, Uvigerinidae, Anomalinidae, Cancrisidae, Discorbidae, Eponididae, Rosalinidae, Nonionidae, Nummulitidae, Planorbulinidae, Cymbaloporidae, Cibicididae, Elphidiidae and Rotaliidae), 36 genera (*Gypsina*, *Acervulina*, *Amphistegina*, *Sagrinella*, *Sigmavirgulina*, *Bolivina*, *Bolivinellina*, *Brizalina*, *Bulimina*, *Loxostomina*, *Trimosina*, *Reussella*, *Siphouvigerina*, *Uvigerina*, *Hanzawaia*, *Cancris*, *Gavelinopsis*, *Eponides*, *Rosalina*, *Nonionella*, *Nonionellina*, *Porosononion*, *Pseudononion*, *Assilina*, *Planorbulina*, *Cibicides*, *Lobatula*, *Cymbaloporetta*, *Cribroelphidium Elphidium*, *Ammonia*, *Asterorotalia*, *Rotalinoides*, *Porosononion*[3], *Ammonia* and *Challengerella*). The order **Textulariida** is represented by one superfamily (Textularioidea), one family (Textulariidae) and three genera (*Sahulia, Spirotextularia* and *Textularia*).

8.3.2 Statistical Analysis

The stations sampled for foraminifera in the Gulf cluster into two groups, Clusters 1 and 2 (Figure 47–48). Cluster 1 includes the farthest stations offshore in the northern sector of the Gulf and stations that are somewhat far from river interaction and characterized by shallow water depths of 16–23 m. The top five taxa in order of their decreasing percentage contribution to Cluster 1 are *Asterorotalia*, *Nonion*, *Bolivina*, *Quinqueloculina* and *Ammonia*. Cluster 2 includes several of the southeastern stations within water depths of 16–45 m, and has more abundant *Quinqueloculina*, *Asterorotalia*, *Textularia*, *Cibicides Bolivina*, and *Hanzawaia*. The average diversity and evenness

[3] Cribroelphidium

of stations in Cluster 2 (H’=2.71, E_H = 0.46) is higher compared to Cluster 1 (H’=2.15, E_H = 0.43). Although the average number of species present for the two clusters are similar, cluster 2 has individuals in the assemblage that are distributed more equitably among these species. Station T 10-2 (H’=1.79, E_H = 0.25) has the highest number of individuals (390), with over 54% of the individuals belong to one taxa, *Nonion*, which is the second most common species in Cluster 2 after *Asterorotalia*. On the other hand, *Nonion* makes up about 2.8 % of the Cluster 1 community. A summary of the diversity indices is presented in Appendix 1. In the R-Mode PCA (Figure 49), 52% of the data variance can be explained by the first two principal components. The first component strongly corresponds to the contributions of *Nonion*, *Bolivina*, *Ammonia*, and *Asterorotalia*, while the second component includes *Bolivina*, *Bulimina, Brizalina*, *Loxostomina*, *Fursenkoina*, *Bolivinella Quinqueloculina*, *Cibicides*, and *Textularia*.

Table 8. Benthic foraminiferal taxa (order, superfamily, family, and genus) and number of species and subspecies identified from the Gulf

Order	Superfamily	Family	Genus	Species number
Astrorhizida	Saccamminoidea	Saccamminidae	*Lagenammina*	1
Lagenida	Nodosarioidea	Lagenidae	*Lagena*	5
		Nodosariidae	*Pyramidulina*	1
	Polymorphinoidea	Ellipsolagenidae	*Fissurina*	3
			Oolina	1
		Glandulinidae	*Glandulina*	5
Lituolida	Lituoloidea	Haplophragmoididae	*Haplophragmoides*	1
	Rzehakinoidea	Trilocularenidae	*Falsagglutinella*	1
	Spiroplectamminoidea	Spiroplectamminidae	*Spiroplectammina*	1
			Spiroplectinella	1
	Verneuilinoidea	Verneuilinidae	*Gaudryina*	5
Miliolida	Milioloidea	Cribrolinoididae	*Adelosina*	7
		Hauerinidae	*Flintina*	1
			Miliolinella	3
			Pseudotriloculina	1
			Pyrgo	2
			Quinqueloculina	31
			Sigmoilopsis	5
			Sigmamiliolinella	1
			Siphonaperta	4
			Triloculina	11
		Spiroloculinidae	*Spiroloculina*	12
	Nubecularioidea	Nubeculariidae	*Nubeculina*	1
			Pseudonubeculina	1
Rotaliida	Acervulinoidea	Acervulinidae	*Gypsina*	1
			Acervulina	2
	Asterigerinoidea	Amphisteginidae	*Amphistegina*	2
	Bolivinitoidea	Bolivinitidae	*Fursenkoina*	2
			Sagrinella	1
			Sigmavirgulina	4
		Bolivinitoidae	*Loxostomina*	3
	Bolivinoidea	Bolivinidae	*Bolivina*	4
			Bolivinellina	1
			Brizalina	3

	Buliminoidea	Buliminidae	*Bulimina*	7
		Trimosinidae	*Trimosina*	1
		Uvigerinidae	*Reussella*	1
			Siphouvigerina	1
			Uvigerina	1
	Chilostomelloidea	Anomalinidae	*Hanzawaia*	3
	Discorboidea	Cancrisidae	*Cancris*	6
		Discorbidae	*Gavelinopsis*	1
		Eponididae	*Eponides*	1
		Rosalinidae	*Rosalina*	5
	Nonionoidea	Nonionidae	*Nonion*	3
			Nonionella	1
			Nonionellina	1
			Porosononion	1
			Pseudononion	1
	Nummulitoidea	Nummulitidae	*Assilina*	1
	Planorbulinidea	Planorbulinidae	*Planorbulina*	1
	Planorbulinoidea	Cibicididae	*Cibicides*	5
			Lobatula	2
		Cymbaloporidae	*Cymbaloporetta*	2
	Rotalioidea	Elphidiidae	*Cribroelphidium*	1
			Elphidium	9
		Rotaliidae	*Ammonia*	6
			Asterorotalia	4
			Challengerella	3
			Rotalinoides	1
Textulariida	Textularioidea	Textulariidae	*Sahulia*	2
			Spirotextularia	1
			Textularia	24

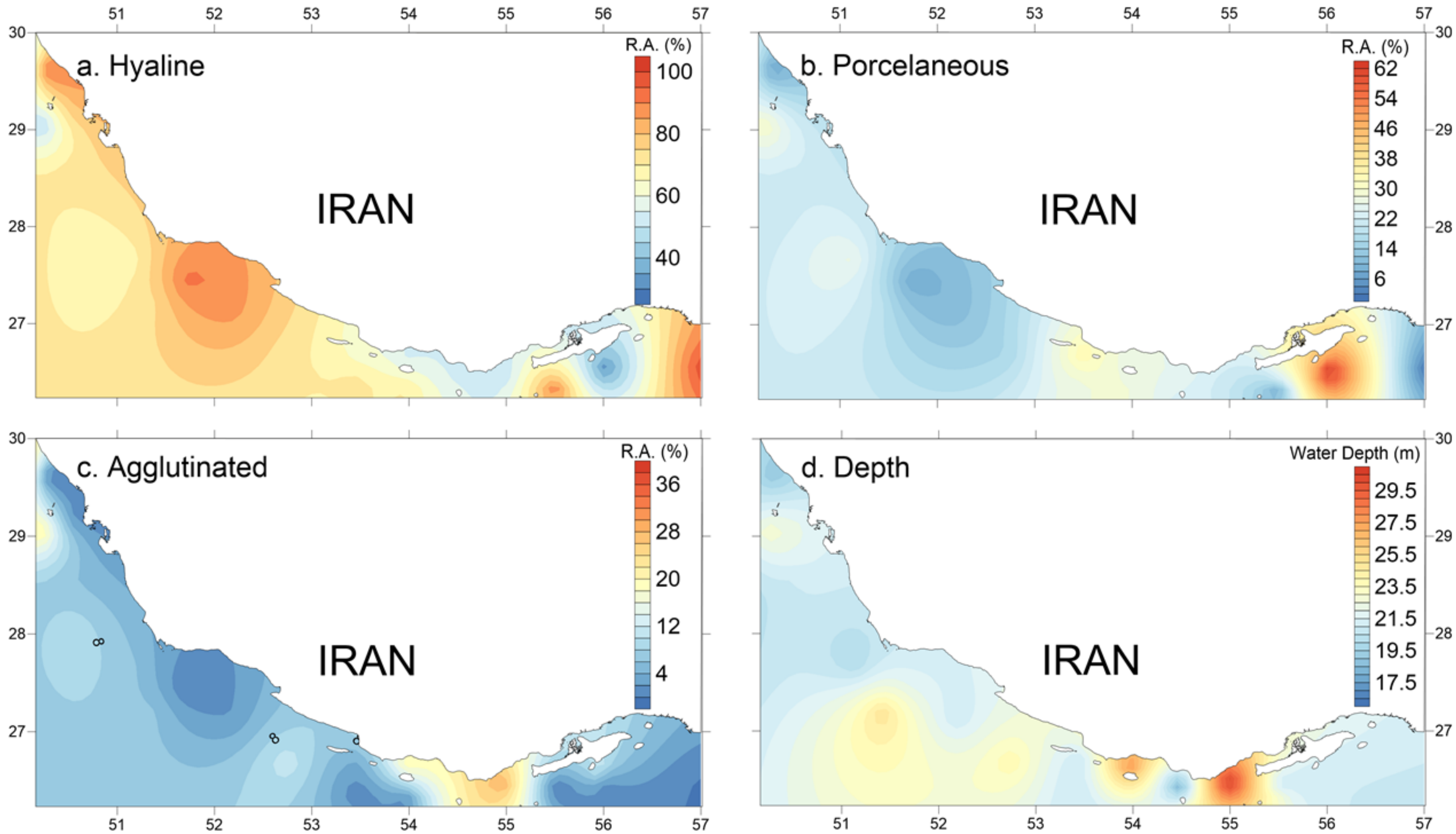

Figure 41. Spatial distribution of major wall types and depth distribution

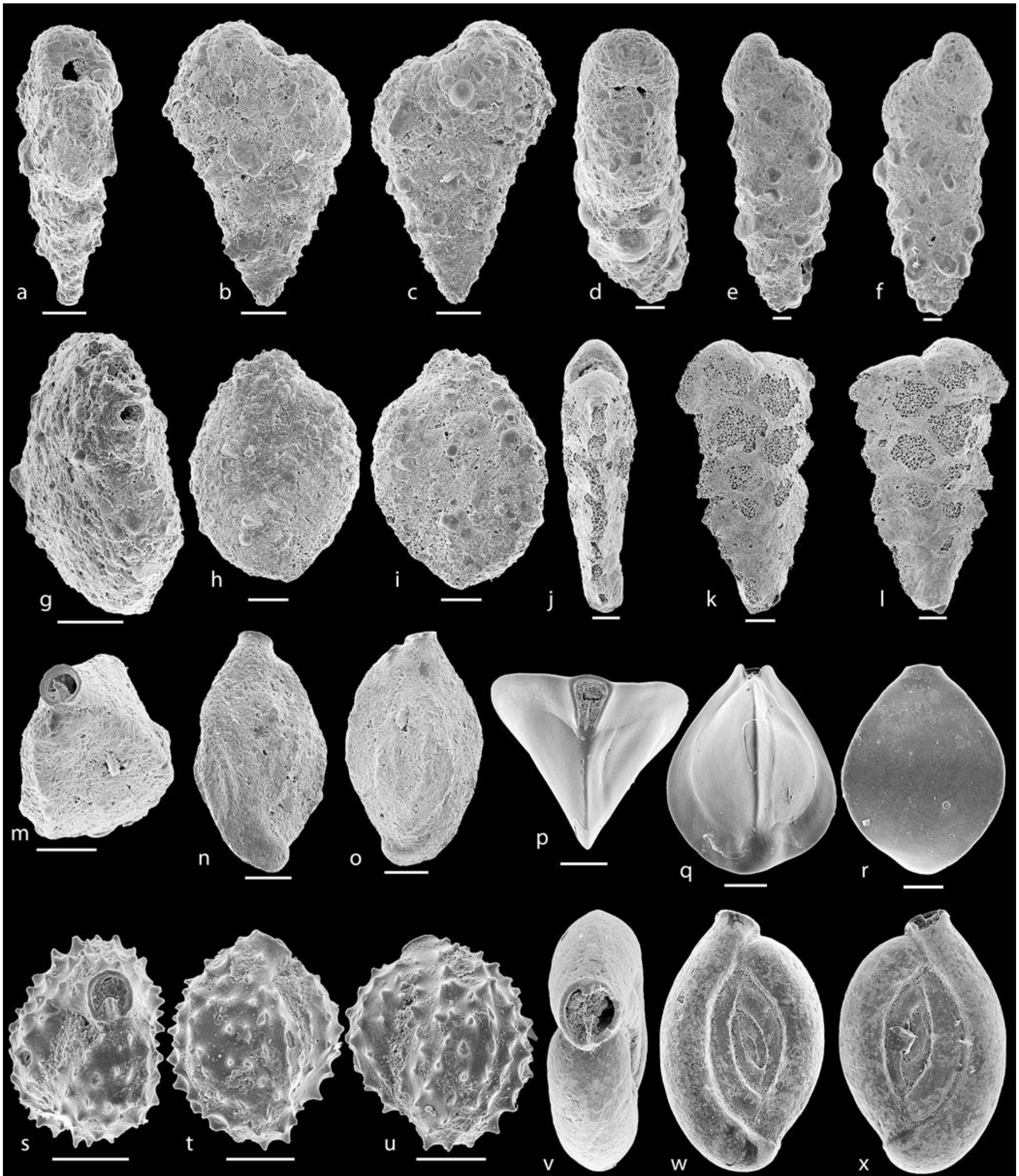

Figure 28.a-c *Textularia foliacea*; (a) apertural view (b) lateral view (c) lateral view of the opposite side. d-e, *Spiroplectammina* sp. 1; (d) apertural view (e) lateral view (f) lateral view of the opposite side. g-i *Sigmoilopsis* sp. 2; (g) apertural view (h) lateral view (i) lateral view of the opposite side. j-l *Spirotextularia* cf. *C. floridana*; (j) apertural view (k) lateral view (l) lateral view of the opposite side. 1m-o *Siphonaperta pittensis*; (m) apertural view (n) lateral view (o) lateral view of the opposite side. p-r *Triloculina tricarinata*; (p) apertural view (q) lateral view (r) lateral view of the opposite side showing the broad chamber. s-u *Quinqueloculina erinacea*; (s) apertural view (t) lateral view (u) lateral view of the opposite side. v-x *Spiroloculina* sp. 1; (v) apertural view (w) lateral view (x) lateral view of the opposite side. All scale bars are 100 µm

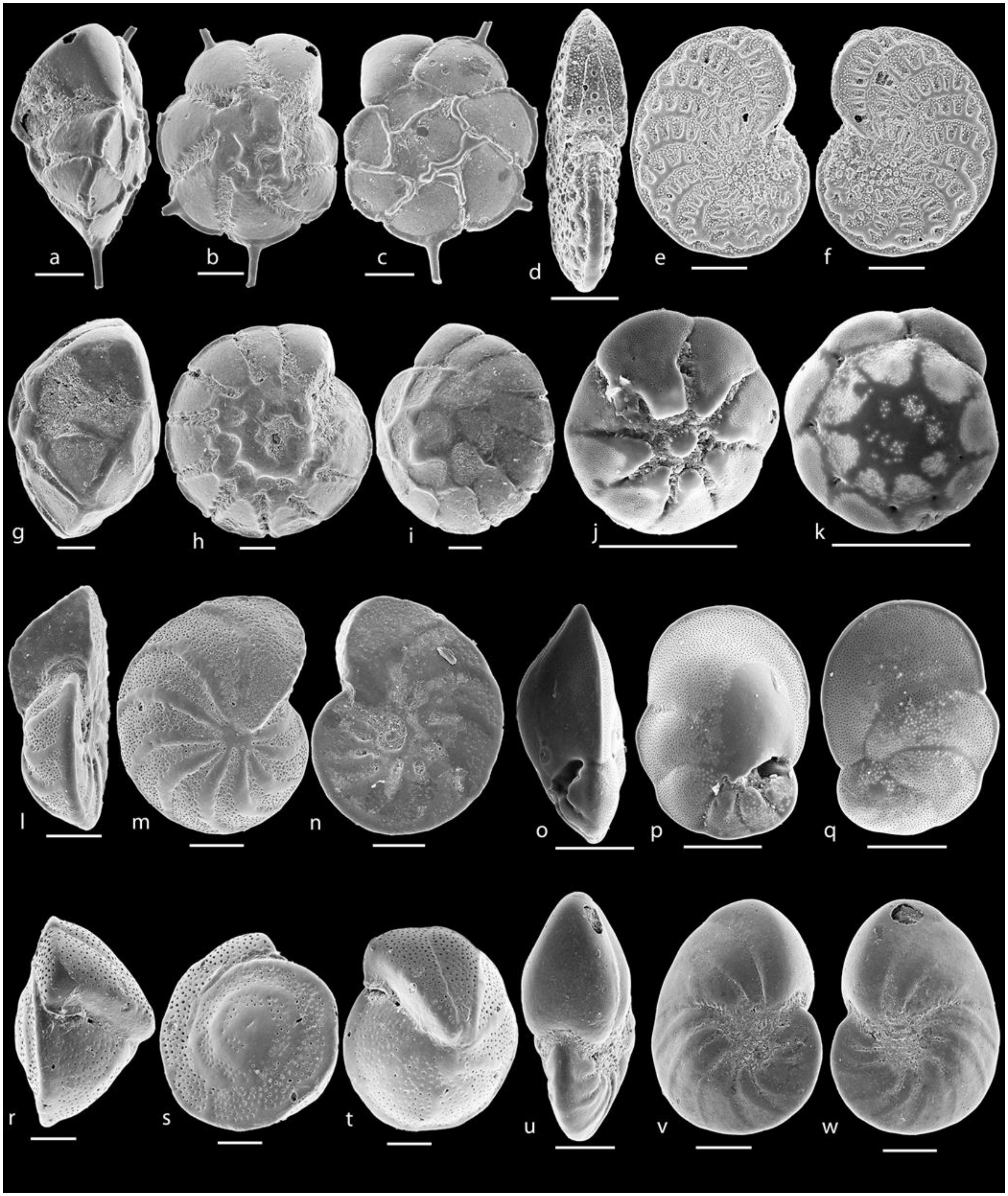

Figure 29. a-c *Asterorotalia* sp. 3; (a) apertural view (b) lateral view (c) lateral view of the opposite side. 2d-e, *Elphidium fichtellianum*; (d) apertural view (e) spiral view (f) umbilical view. g-i *Challengerella* sp. 3; (g) apertural view (h) lateral view (i) lateral view of the opposite side. j-l *Ammonia convexa*; (j) umbilical view (k) spiral view. l-n *Hanzawaia* sp. 6 (l) apertural view (m) lateral view (n) lateral view of the opposite side. o-q *Cancris* cf. *C. auriculus*; (o) apertural view (p) lateral view (q) lateral view of the opposite side showing the broad chamber. r-t *Cibicides* cf. *C. refulgens*; (r) apertural view (s) lateral view (t) lateral view of the opposite side. u-w *Nonion* sp. 2; (u) apertural view (v) lateral view (w) lateral view of the opposite side. All scale bars are 100 µm

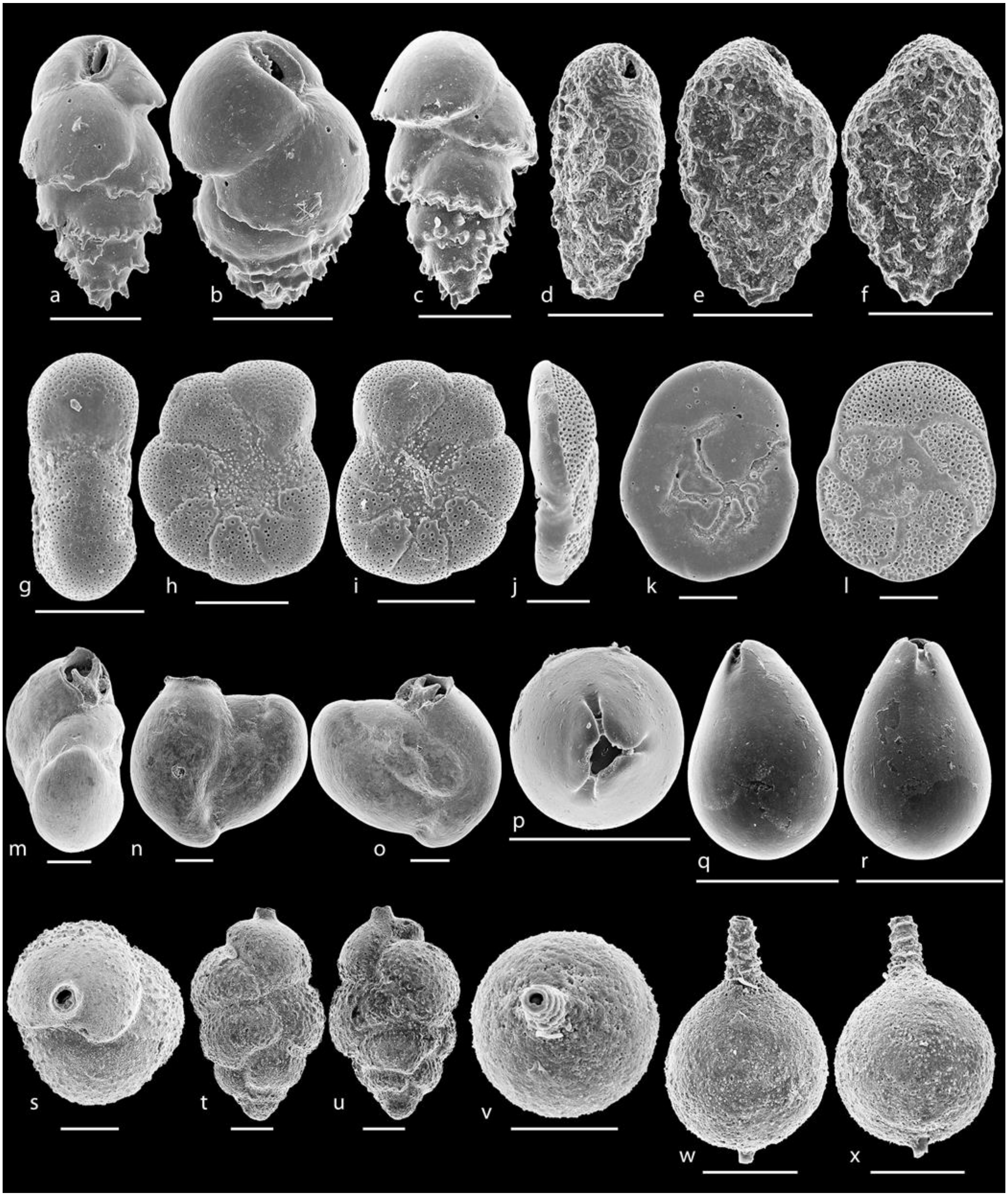
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Figure 44. a–c *Bulimina marginata*; (a) apertural view (b) lateral view (c) lateral view of the opposite side. d–e, *Bolivina* cf *B. persiensis*; (d) apertural view (e) lateral view (f) lateral view of the opposite side. g–i *Porosononion* sp. 1; (g) apertural view (h) lateral view (i) lateral view of the opposite side. j–l *Rosalina bradyi*; (j) apertural view (k) lateral view (l) lateral view of the opposite side. The following four species are representative of the least abundant groups. m–o *Flintina* sp. 1; (m) apertural view (n) more involute side view (r) more evolute side view. p–r (?) *Oolina* sp. 1; (p) apertural view (q) lateral view (r) lateral view of the opposite side. s–u *Siphouvigerina proboscidea*; (s) apertural view (t) lateral view (u) lateral view of the opposite side. v–x *Lagena* sp. 1; (v) apertural view (w) lateral view (x) lateral view of the opposite side. All scale bars are 100 µm

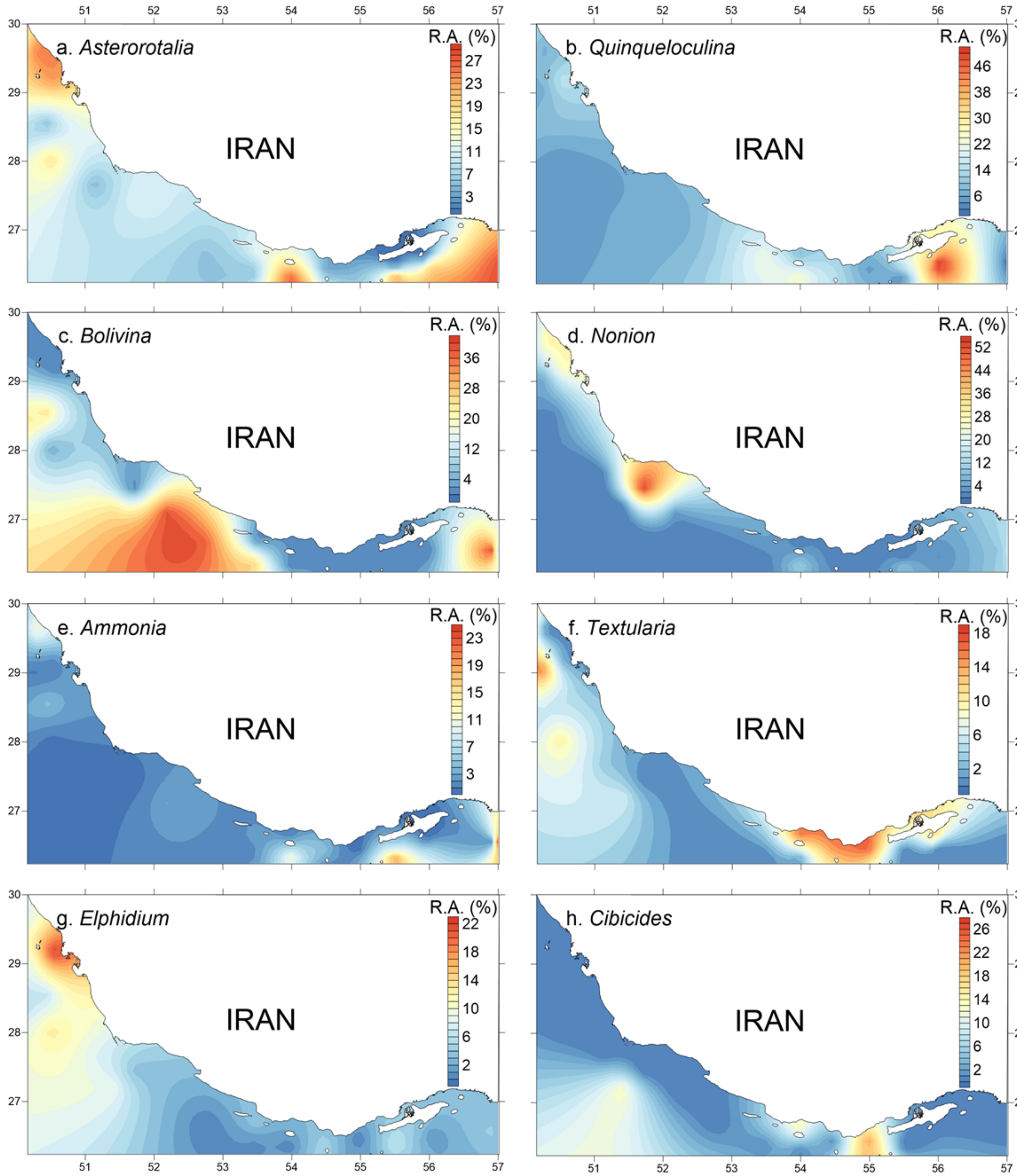

Figure 30. Distribution maps of the most abundant taxa recognized in the Gulf; a. *Asterorotalia* b. *Quinqueloculina* c. *Bolivina* d. *Nonion* e. *Ammonia* f. *Textularia* g. *Elphidium* h. *Cibicides*. Relative abundance (R.A.)

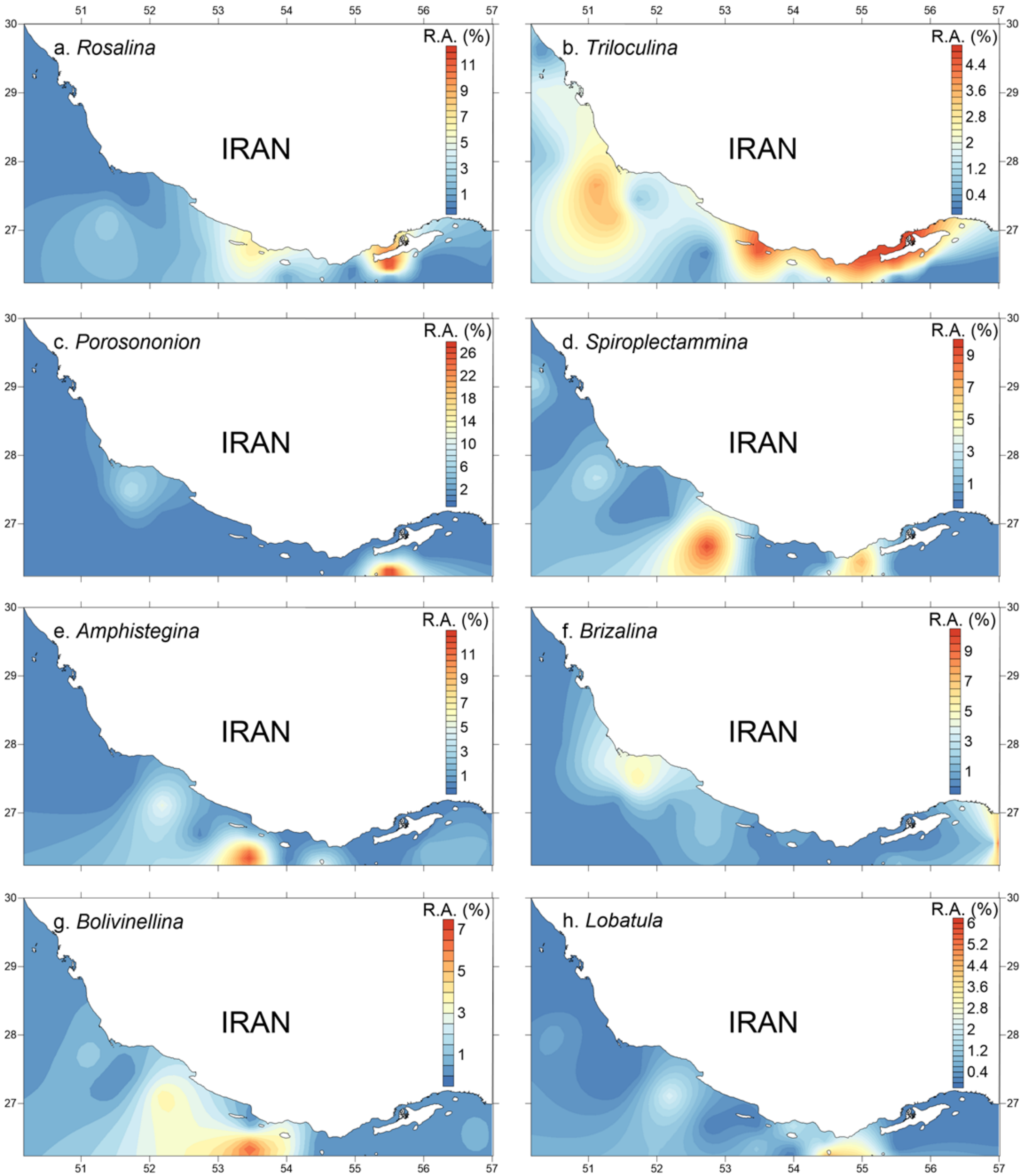

Figure 31. Distribution maps of the most abundant taxa recognized in the Gulf; a. *Rosalina* b. *Triloculina* c. *Porosononion* d. *Spiroplectammina* e. *Amphistegina* f. *Brizalina* g. *Bolivinellina* h. *Lobatula*

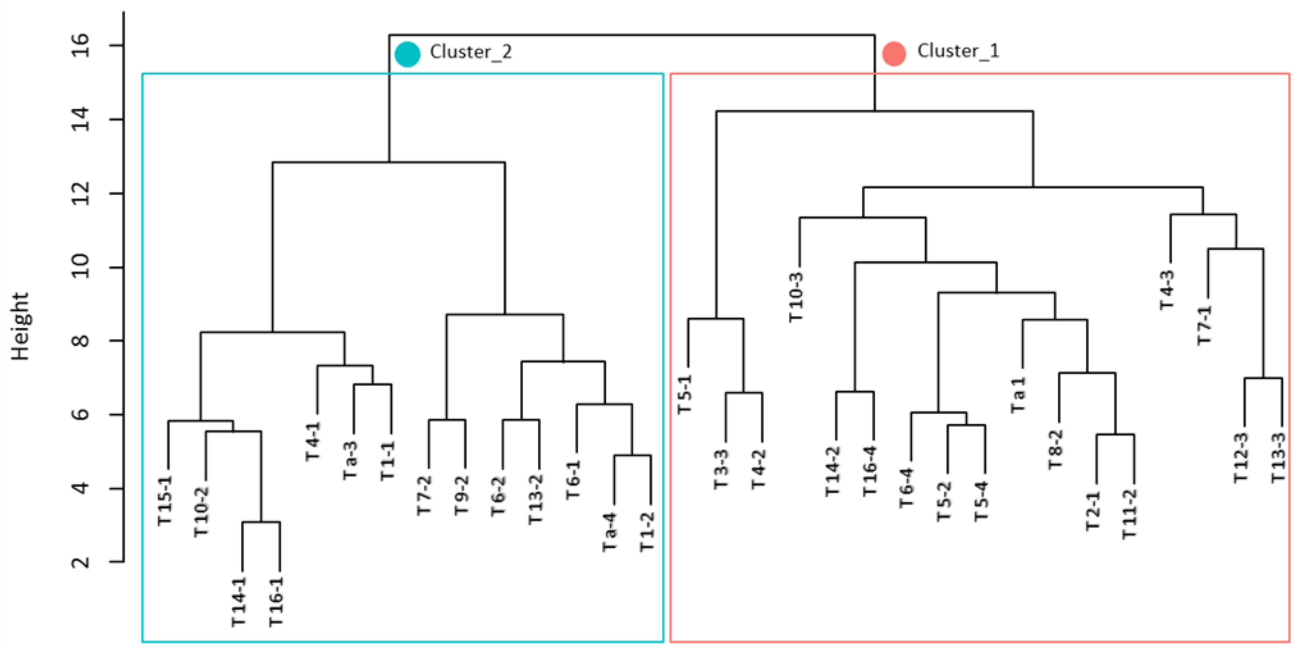

Figure 32. Q-mode Cluster Analysis

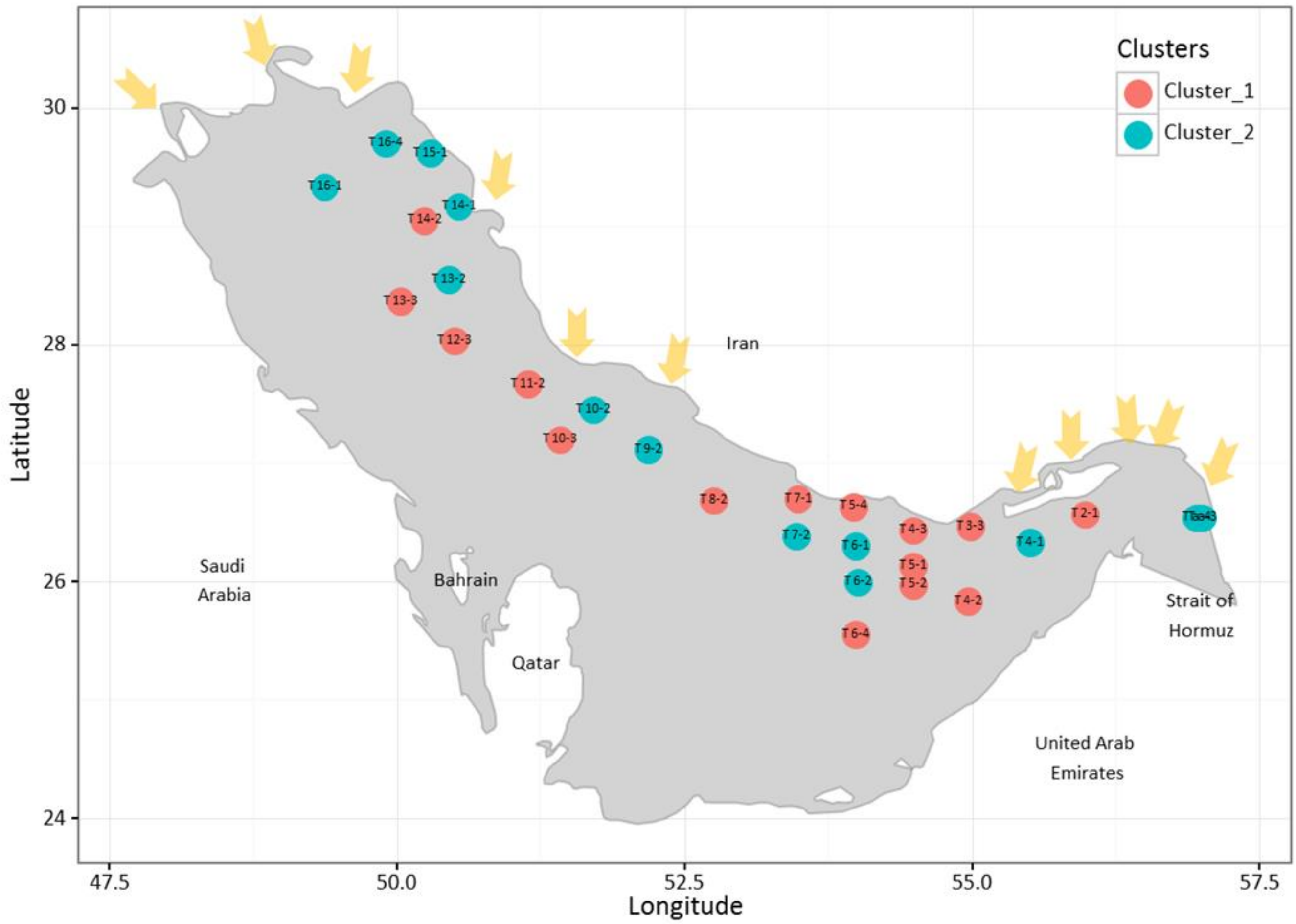

Figure 33. Spatial distribution of the two main clusters and yellow arrows showing point of discharge of rivers and the major ephemeral streams in the Gulf. The arrows approximate the direction of the river deltas

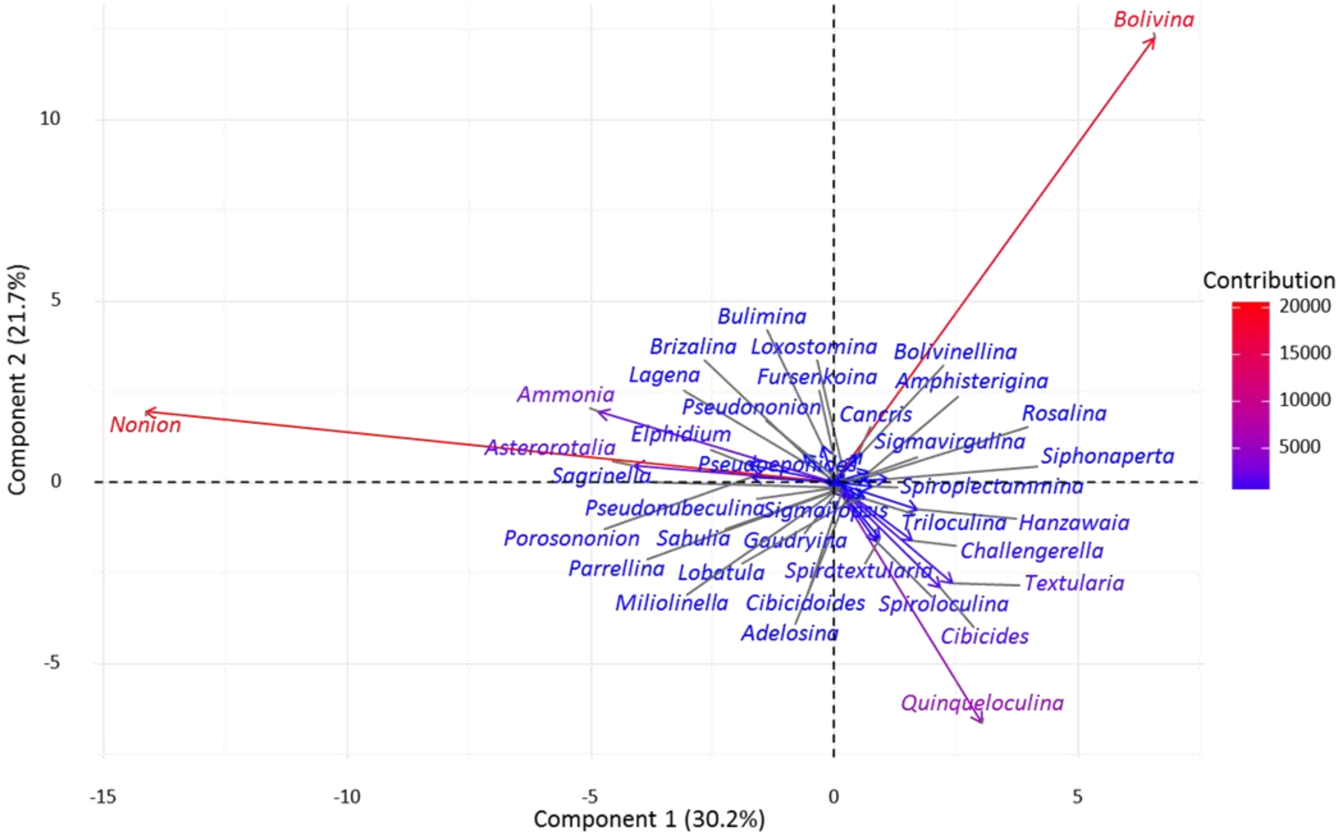

Figure 34. R-mode PCA, with scale showing contribution from individual taxa

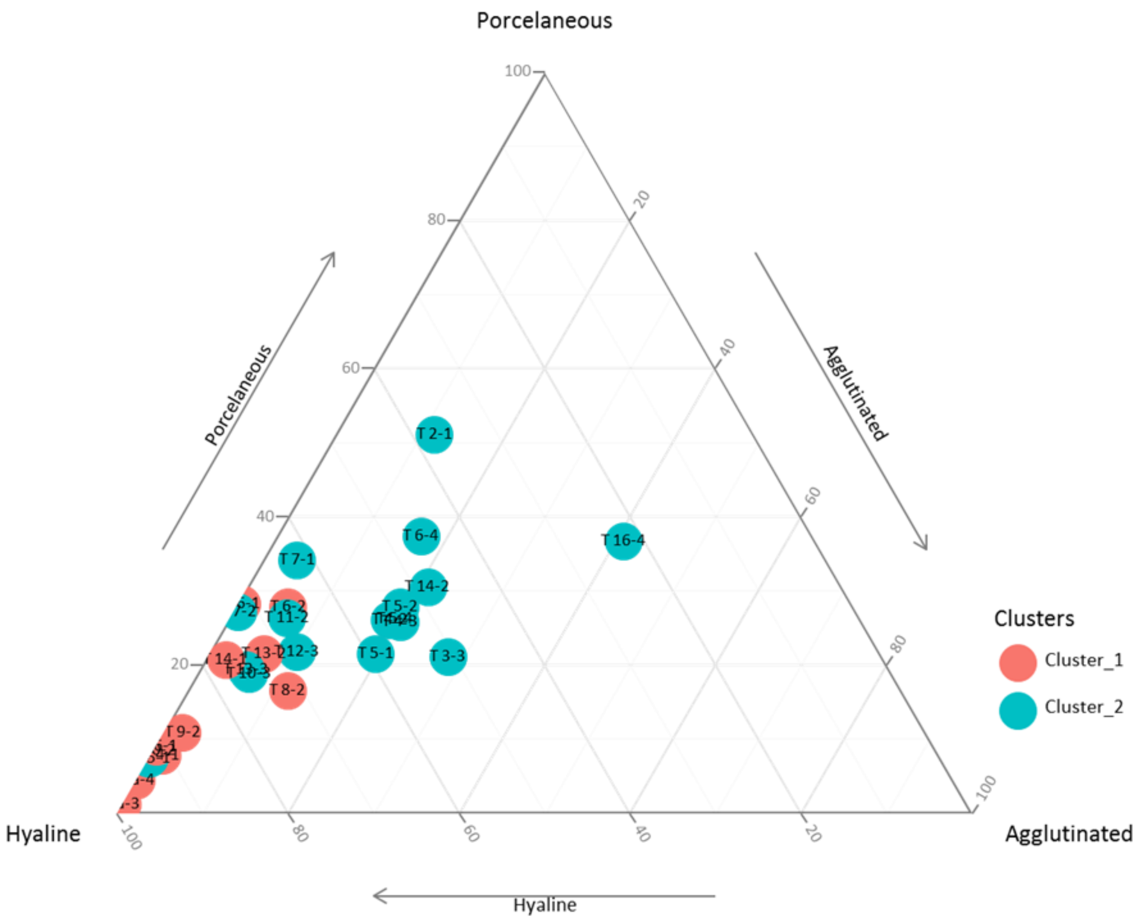

Figure 35. Ternary plot showing wall types as a function of each cluster. Note the arrangement of cluster 1 stations

8.4 Discussion

Establishing reliable spatial changes for each foraminiferal species over a large area (stretching over 1000 km) can be difficult and may not convey tangible scientific information in this study. This is due to some limitations of this study such as (i) the nature of the samples (time averaged), (ii) the gear used in sampling (grab samples), (iii) sedimentary and geochemical data not documented, and (iv) lack of a taxonomic guide for the Gulf. However, the data are robust enough to document spatial changes among major foraminiferal groups (genera). These generalized methods may lack the taxonomic information necessary for detailed local studies, but are essentially regional and should be applied in such a manner. A summary of all the species encountered, groups, and counts are presented as supplementary data and attached as Appendix 2**.**

8.4.1 Diversity and distribution of benthic foraminifera

Most of the species were identified to the genus level in the absence of type material and similar species in the same geographical area. This approach allows for the assessment of diversity within the region and documentation for future taxonomic work. Also, this was to avoid a common tendency among foraminiferal taxonomists to define or elevate new species on the basis of subtle morphologic differences, thereby raising subspecies to species rank (Murray, 2007). It should be noted however, that total assemblages (living and dead foraminifera; time averaged) were consider in this study and therefore allochthonous taxa transported from other environments cannot be excluded, especially from stations close to the Strait of Hormuz. Also, the Order Allogromiida and the Suborder Globigerinina were not considered in this study. Foraminiferal classification based on wall types does not clearly show any major trend, rather than the overall dominance of the hyaline group. However, the average porcelaneous taxa value obtained in this study (Figure 41,

50) is similar to those observed in other land-locked marginal seas, such as the Mediterranean and Red Sea. The plots also show the relationships of the stations based on clustering and wall type, supporting the initial suggestion on the factors controlling foraminifera distribution. The use of ternary plots in foraminiferal studies became universal after the pioneering work of Murray (1970a). The plots reflect the salinity regime in an area by comparing the contribution of taxa based on wall types. Porcelaneous foraminiferal percentages for the Gulf central axis represented by four stations are typical of shelf conditions (Murray, 1991), that is, stations with porcelaneous representation less than 20% in the total assemblage composition are indicative of shelf conditions, while values greater than 20% can be found in normal marine, hypersaline, or marsh environments. This also corroborates the findings of Reynolds (1993), who noted that bottom water masses in the central axis of the Gulf have lower salinity.

The dynamics of foraminiferal assemblages do not follow a northeast to southeast trend of the major freshwater input at the north-central part of the Gulf while normal marine water enters into the Gulf through the strait of Hormuz at the southeast end. The spatial distribution of foraminifera in the Gulf appears patchy (Figure 45, 46), this may be due to localized ecological requirement of each group and the complex submarine geology of the area. Many larger shallow benthic foraminifera species (e.g., *Sorites*, *Vertebralina*, *Peneroplis*, and *Coscinospira*), which are indicative of shallow depths and oligotrophic conditions in the northwestern parts of the Gulf (Parker and Gischler, 2015; Amao et al., 2016b), were not found in this study. This corroborates the distribution pattern of foraminifera along a bathymetric transect in the Gulf suggested by Parker and Gischler (2015). Several species distributed along the over 1000 km coast samples have relative abundances <5%. Among these groups, species that are new to science were found [e.g. *Pseudonubeculina arabica* (Abduljamiu Olalekan Amao and Kaminski, 2016)]. These are groups commonly excluded from multivariate data analysis by modern computational techniques such as CA and PCA (Hayek and Buzas, 2013). Their patchiness may indicate low preservation potential or seasonality can contribute significantly to the environment in which they are found. The progressive disappearance some groups [e.g., *Nonion*, *Cibicides*, *Rosalina* etc. (Figure 45, 46)] from southeast to northeast within the Gulf and influences of environmental parameters, such as river discharge that is a product of the environmental and geological characteristics of the surrounding areas, may suggest an arbitrary subdivision of the Gulf (Cherif et al., 1997; Riegl et al., 2010).

8.4.2 Controls on benthic foraminifera distribution

In the R-Mode PCA (Figure 49), the first component (axis 1) that justifies 30.2% of total variance is negatively related to *Nonion*, *Ammonia*, *Elphidium* and *Asterorotalia* and positively to *Rosalina*, *Hanzawaia*, and *Textularia*. Also these assemblages correspond to most abundant taxa in CA cluster 1 (Figure 47). The known ecology of these taxa suggests that some taxa negatively related to axis 1 are herbivores whereas those positively related to axis 1 are mainly epifaunal or attached (i.e., epiphytic) with some having preference for hard substrate (epilithic) (Murray, 2006). Tentatively, this axis might be interpreted as a gradient in the dominant feeding strategy, from herbivore (*Nonion*, *Ammonia*, *Elphidium* and *Asterorotalia*) to detritivore (*Textularia*), omnivore (*Rosalina*), or suspension feeder (*Siphonaperta*, *Hanzawaia*). These ecological requirements are concordant to the sedimentary regimes of the area which have been described as having sediments with bioclastic fragments including coral, coralline algal fragments, mollusk, echinoid fragment, abundant foraminifera and fine muddy sediments (Purser, 1973; Riegl et al., 2010). There are regions with a mixture of several subenvironments such as submarine highs, areas with high sedimentation rates, small patches in high energy conditions formed as sand bars and tails downwind from reefs, etc.

On the other hand, the second axis explaining 21.7% of the total variance is positively related to *Bulimina*, *Brizalina*, *Loxostomina*, *Fursenkoina*, *Bolivinella* and *Bolivina* and negatively to *Quinqueloculina*, *Adelosina*, *Spiroloculina*, *Cibicides*, *Cibicidoides*, and *Lobatula*, and constitute some of the most abundant members of cluster 2. The known ecology of these taxa suggests that most or all taxa (all biserial/triserial) positively related to axis 2 are infaunal and have a preference for muddy substrate (dysoxic taxa), whereas those taxa (porcelaneous and low trochospiral forms) that are negatively related to axis 2 are epifaunal and have a preference for hard substrate. In light of this, axis 2 might be interpreted as increase of finer material and possibly with the increase of nutrients and the reduction of oxygen within the sediment. In cluster 2, stations T16-1, T16-4, T14-1, T10-2, T9-2, Ta-3 and Ta-4 are close to river and ephemeral stream discharge points along the Iranian Coast (Figure 48). These are areas that have been described in the literature (Purser, 1973; Riegl et al., 2010) as having high percentages of mud and are characterized by the presence of pelecypod fragments, very small mollusk shells, and foraminifera that are typical of distal homocline and distal deep marine areas. In addition, Saidova (2010) indicated that *Quinqueloculina*, *Asterorotalia*, and *Textularia* show preference for areas with zero to minimal river discharge, whereas communities with *Nonion* and *Cancris* are found in areas with intermediate warm water layers influenced by river discharge and terrigenous sedimentation. On the other hand, *Brizalina* has been reported to dominate in areas of upwelling and parts of the ocean where the average water temperature is significantly lower compared to that which is usual for subtropical latitudes. This is concordant to interpretation in this study and the distribution of the clusters.

8.5 Conclusions

Benthic foraminiferal species diversity has been investigated along over 1000-km-long sampled transect from the northeast to southeast of the Gulf along the Iranian sector. A total of 224 species and subspecies belonging to 63 genera, 34 families, 22 superfamilies and 6 orders are documented herein. The most significant contributions are from genera such as *Nonion*, *Bolivina*, *Quinqueloculina*, *Cibicides*, *Ammonia*, *Asterorotalia* and *Textularia*. The number of species and subspecies in this study is more than twice the previous values reported for the entire and western parts of the Gulf. With additional taxonomic effort on a local scale, however, the true number of species in the Gulf is likely to be considerably higher. The diversity of benthic foraminifera in the Gulf is not directly comparable with the Red and Mediterranean seas due to the large differences in water depth and variety of habitats; the values obtained in this study suggest a regionally high foraminiferal diversity in a subtropical-shelf, carbonate-ramp environments. We speculate that feeding strategy, (e.g., herbivores *Nonion, Ammonia, Elphidium and Asterorotalia*), the heterogeneous distribution of finer sediments (mud), availability of nutrients and presence of oxygen are factors controlling the diversity and distribution of benthic foraminifera in the eastern Gulf.

CHAPTER 9

How many benthic foraminifera live in the Arabian Gulf?

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SUMMARY-- This study focuses on the distribution of living benthic foraminifera offshore in the Arabian Gulf and establishes the total biodiversity for the area by collating all published works on foraminifera in the region. Historical records on foraminiferal diversity and distribution in the Gulf commonly underestimate its benthic foraminiferal composition and diversity. A total of 271 living benthic foraminiferal species and subspecies were identified belonging to 66 genera, 37 families, 23 superfamilies and six orders. They are further grouped by dominant wall types: hyaline (45%), porcelaneous taxa (42%), agglutinated (13%), while the spirillinid group, which is often referred to as having an optically single crystal or a mosaic of few crystals has 1% representation. We estimate a total of 534 species and subspecies belonging to 123 genera, 54 families and 30 superfamilies have been recorded so far in the Gulf based on available literature documenting foraminifera, coupled with data from this research. These new findings probably better reflect the real diversity of the Gulf. However, many modern foraminiferal taxa in the Gulf are reported in open nomenclature or are only tentatively identified. This study updates the knowledge on the type and autochthonous distribution of benthic foraminiferal groups.

9.1 Introduction

The well being and welfare of the Arabian Gulf countries largely depends on the marine environment for food, transportation of economic goods, and other services. The progressive degradation of the marine environment in the Arabian Gulf is a result of rapid urbanization and development. The conditions are also confounded by the already extreme natural environmental parameters prevailing in the region. Never before has there been a more urgent plea for keeping it pollution-free than today when the world is in a dire need of clean environment for human survival. Several initiatives are currently in place to salvage the situation but such efforts are few and far between. It is however the responsibility of the state and the neighboring countries to the Gulf to work together and proffer a cooperative cross boundary solution to the threats directly impacting the Arabian Gulf through constant monitoring and remediation programs.

9.1.1 Geography and Geological Setting

See Chapter 1

9.1.2 Previous foraminiferal studies in the Gulf

See Chapter 2

9.2 Methodology

9.2.1 Sampling

Thirty-two samples were collected offshore in northen Arabian Gulf (Figure 51) using a Van Veen grab (0.1 m^2 area). Top 2 cm of the grab was subsample and preserved using 70% ethanol with Rose-Bengal stain. In the laboratory, after two weeks allotted for proper staining, samples were wet-sieved through a 63 µm mesh sieve, dried, and later split into equal aliquots using a microsplitter to generate subsamples with approximately 300 benthic foraminiferal tests (living assemblage). Specimens were picked quantitatively from the 63 µm fraction.

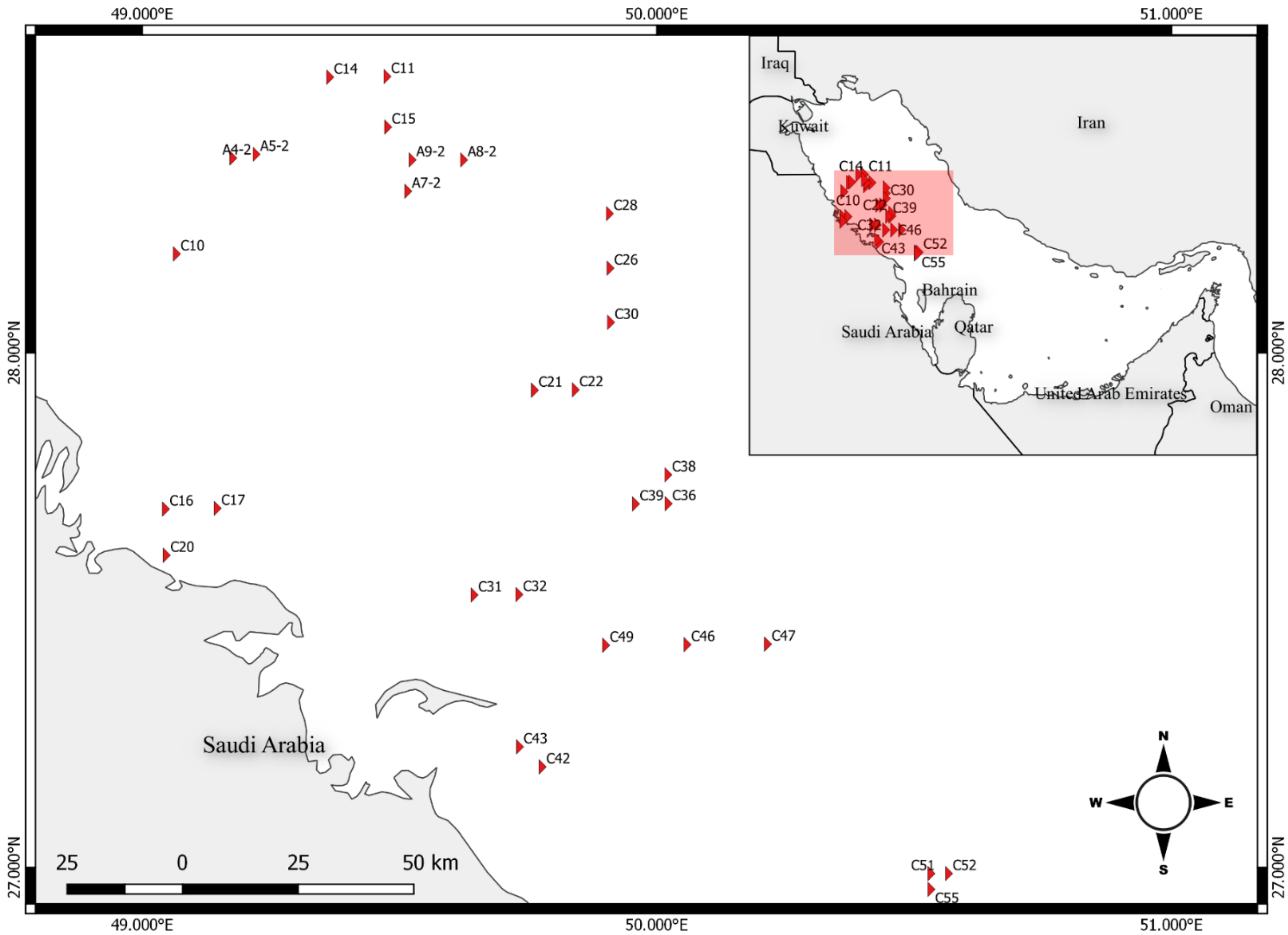

Figure 36. Current study sampling location map with region overview map showing extent of the Gulf and bordering countries

Living Benthic Foraminifera

A total of 271 living benthic foraminiferal species and subspecies were identified belonging to 66 genera, 37 families, 23 superfamilies and six orders (Table 9). They further grouped by dominant wall types: hyaline (45%), porcelaneous taxa (42%), agglutinated (13%), while the spirillinid group, which is often referred to as having an optically single crystal or a mosaic of a few crystals, has 1% representation. The ten most abundant species are: *Quinqueloculina seminula* (6.2%), *Miliolinella subrotunda* (5.1%), *Elphidium neosimplex* (4.9%), *Asterorotalia dentata* (4.9%), *Triloculina tricarinata* (4.3%), *Cancris auricularis* (2.7%), *Spiroloculina* sp. 2 (2.4%), *Q. lamarckiana* (2.4%), *M. lutea* (2%), and *Hanzawaia* sp. 1 (1.8%).

Based on WoRMS (2016) hierarchical taxonomic groupings of foraminifera, six orders of benthic foraminifera are recognized from offshore Arabian Gulf within the Saudi Arabian territorial waters. These include the following six orders: Lagenida, Lituolida, Miliolida, Rotaliida, Spirillinida and Textulariida (Table 9). The order **Lagenida** is represented by two superfamilies, six families and ten genera. Four superfamilies, five families and six genera were documented for the order **Lituolida**. The order **Miliolida** has three super families, seven families and 17 genera. The order **Rotaliida** has the highest representation, 11 superfamilies, 16 families and 28 genera. The order **Spirillinida** has no superfamily, but has one family (Spirillinidae) and one genus (*Spirillina*). The order **Textulariida** is represented by two superfamilies (Eggerelloidea and Textularioidea), two families (Valvulinidae and Textulariidae) and four genera (*Clavulina*, *Sahulia*, *Spirotextularia* and *Textularia*).

Table 9. Benthic foraminiferal taxa (order, superfamily, family, and genus) and number of species and subspecies identified from the Gulf.

Order	SuperFamily	Family	Genus	Species number
Lagenida	Nodosarioidea	Lagenidae	*Hyalinonetrion*	1
			Lagena	5
			Procerolagena	1
		Nodosariidae	*Pyramidulina*	2
		Vaginulinidae	*Lenticulina*	1
			Siphomarginulina	2
	Polymorphinoidea	Ellipsolagenidae	*Fissurina*	3
			Pygmaeoseistron	1
		Glandulinidae	*Glandulina*	3
		Polymorphinidae	*Guttulina*	1
Lituolida	Lituoloidea	Lituolidae	*Ammobaculites*	1
	Recurvoidoidea	Ammosphaeroidinidae	*Cribrostomoides*	1
	Spiroplectamminoidea	Nouriidae	*Nouria*	1
		Spiroplectamminidae	*Spiroplectammina*	2
			Spiroplectinella	1
	Verneuilinoidea	Verneuilinidae	*Gaudryina*	4
Miliolida	Milioloidea	Cribrolinoididae	*Adelosina*	10
		Hauerinidae	*Ammomassilina*	1
			Biloculinella	2
			Miliolinella	5
			Pseudomassilina	1
			Pseudotriloculina	1
			Pyrgo	4
			Quinqueloculina	39
			Sigmamiliolinella	2
			Sigmoilopsis	6
			Siphonaperta	8
			Triloculina	11
		Miliolidae	*Rupertianella*	1
		Spiroloculinidae	*Spiroloculina*	18
	Nubecularioidea	Fischerinidae	*Wiesnerella*	1
		Ophthalmidiidae	*Edentostomina*	2
	Soritoidea	Soritidae	*Sorites*	1
Rotaliida	Asterigerinoidea	Amphisteginidae	*Amphistegina*	1
	Bolivinitoidea	Bolivinitidae	*Fursenkoina*	2
			Loxostomina	1
			Sagrinella	2

			Sigmavirgulina	4
	Bolivinoidea	Bolivinidae	*Bolivina*	4
			Brizalina	3
	Buliminoidea	Buliminidae	*Bulimina*	5
		Reussellidae	*Reussella*	4
	Chilostomelloidea	Anomalinidae	*Cibicidoides*	2
			Hanzawaia	4
	Discorboidea	Cancrisidae	*Cancris*	6
		Discorbidae	*Gavelinopsis*	1
		Rosalinidae	*Rosalina*	9
	Nonionidea	Nonionidae	*Nonion*	4
	Nonionoidea	Nonionidae	*Nonionella*	2
			Nonionellina	1
			Nonionoides	1
	Nummulitoidea	Nummulitidae	*Operculina*	3
	Planorbulinoidea	Cibicididae	*Cibicides*	6
			Lobatula	2
		Cymbaloporidae	*Cymbaloporetta*	4
			Millettiana	1
	Rotalioidea	Elphidiidae	*Cribroelphidium*	2
			Elphidium	11
		Rotaliidae	*Ammonia*	8
			Asterorotalia	6
			Challengerella	2
Spirillinida		Spirillinidae	*Spirillina*	2
Textulariida	Eggerelloidea	Valvulinidae	*Clavulina*	1
	Textularioidea	Textulariidae	*Sahulia*	4
			Spirotextularia	2
			Textularia	18

9.3 Discussion and Conclusions

The actual numbers of foraminifera in the Arabian Gulf might never be known for several reasons such as the degree of patchness, current methodologies, bias in sampling, differences in focus of studies and sampling strategies, and the general inability to sample the entire marine environment. However, reliable estimates can be obtained based on extensive review of available literature on benthic foraminifera in the region dating back to the 1960's. This study has documented over 830 species and subspecies based on its findings and literature review.

CHAPTER 10

Atlas of Benthic Foraminifera of the Arabian Gulf

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To be submitted to Micropaleontology

10.1 Systematics of benthic foraminifera identified

Astrorhizida Lankester, 1885
  Saccamminoidea Brady, 1884
    Saccamminidae Brady, 1884
      Lagenammina Rhumbler, 1911
        Lagenammina sp
Lagenida Delage & Hérouard, 1896
  Nodosarioidea Ehrenberg, 1838
    Lagenidae Reuss, 1862
      Hyalinonetrion Patterson & Richardson, 1988
        Hyalinonetrion gracillimum (Seguenza, 1862)
      Lagena Schumacher, 1817
        Lagena cf. L. *semistriata* Williamson, 1848
        Lagena cf. L. *strumosa* Reuss, 1858
        Lagena semistriata Williamson, 1848
        Lagena sp. 1
        Lagena striata (d'Orbigny, 1839)
        Lagena strumosa Reuss, 1858
      Procerolagena Puri, 1954
        Procerolagena sp. 1
    Nodosariidae Ehrenberg, 1838
      Pyramidulina Fornasini, 1894
        Pyramidulina catesbyi (d'Orbigny, 1839)
        Pyramidulina sp. 1
    Vaginulinidae Reuss, 1860
      Lenticulina Lamarck, 1804
        Lenticulina sp.
      Siphomarginulina McCulloch, 1981
        Siphomarginulina sp. 1
        Siphomarginulina sp. 2
  Polymorphinoidea
    Ellipsolagenidae A. Silvestri, 1923
      Fissurina Reuss, 1850
        Fissurina cf. F. *bispinata* Ujiié, 1963
        Fissurina lucida (Williamson, 1848)
        Fissurina sp. 2
      Oolina d'Orbigny, 1839
        Oolina sp. 1
        Oolina cf. *O. baukalionilla* Loeblich & Tappan, 1994
      Pygmaeoseistron Patterson & Richardson, 1988
        Pygmaeoseistron sp. 1
    Glandulinidae Reuss, 1860
      Glandulina d'Orbigny, 1839
        Glandulina cf. *G. laevigata* d'Orbigny, 1826

Glandulina ovula d'Orbigny, 1846
Glandulina sp. 1
Glandulina sp. 2
Glandulina sp. 3
Glandulina suezensis McCulloch, 1977
Polymorphinidae d'Orbigny, 1839
Guttulina d'Orbigny, 1839
Guttulina yamazaki Cushman & Ozawa, 1930
Lituolida Lankester, 1885
Lituoloidea
Haplophragmoididae Maync, 1952
Trochamminopsis Brönnimann, 1976
Trochamminopsis pusilla (Höglund, 1947)
Lituolidae de Blainville, 1827
Ammobaculites Cushman, 1910
Ammobaculites sp. 1
Ammobaculites sp. 2
Recurvoidoidea Alekseychik-Mitskevich, 1973
Ammosphaeroidinidae Cushman, 1927
Cribrostomoides Cushman, 1910
Cribrostomoides jeffreysii (Williamson, 1858)
Rzehakinoidea Cushman, 1933
Trilocularenidae Mikhalevich & Kaminski, 2008
Falsagglutinella Loeblich & Tappan, 1994
Falsagglutinella cf. *F. angularis*
Spiroplectamminoidea Cushman, 1927
Nouriidae Chapman & Parr, 1936
Nouria Heron-Allen & Earland, 1914
Nouria polymorphinoides Heron-Allen & Earland, 1914
Spiroplectamminidae
Spiroplectammina
Spiroplectammina sagittula (Defrance, 1824)
Spiroplectammina sp. 1
Trochamminoidea Schwager, 1877
Trochamminidae
Trochammina
Trochammina inflata (Montagu, 1808)
Trochammina squamata Jones & Parker, 1860
Verneuilinoidea Cushman, 1911
Verneuilinidae
Gaudryina
Gaudryina attenuata Chapman, 1902
Gaudryina convexa (Karrer, 1865)
Gaudryina sp. 2
Gaudryina sp. 3

Gaudryina sp. 4

Miliolida Delage & Hérouard, 1896

Cornuspiroidea Schultze, 1854

Cornuspiridae Schultze, 1854

Cornuspira Schultze, 1854

Cornuspira cf. *C. planorbis* Schultze, 1853

Cornuspira planorbis Schultze, 1853

Milioloidea Ehrenberg, 1839

Cribrolinoididae Haynes, 1981

Adelosina d'Orbigny, 1826

Adelosina cf. *A. mediterranensis* (Le Calvez, J. & Y., 1958)

Adelosina longirostra (d'Orbigny, 1846)

Adelosina mediterrranensis (Le Calvez, J. & Y., 1958)

Adelosina pulchella (d'Orbigny, 1826)

Adelosina sp. 1

Adelosina sp. 2

Adelosina sp. 3

Adelosina sp. 4

Adelosina sp. 5

Adelosina sp. 6

Adelosina sp. 7

Adelosina sp.8

Hauerinidae Schwager, 1876

Agglutinella El-Nakhal, 1983

Agglutinella arenata (Said, 1949)

Agglutinella compressa El-Nakhal, 1983

Agglutinella robusta El-Nakhal, 1983

Agglutinella soriformis El-Nakhal, 1983

Ammomassilina Cushman, 1933

Ammomassilina clypeoarenula Loeblich & Tappan, 1994

Articulina d'Orbigny, 1826

Articulina alticostata Cushman, 1944

Articulina pacifica Cushman, 1944

Biloculinella Wiesner, 1931

Biloculinella sp. 1

Biloculinella inflata (Wright, 1902)

Biloculinella wiesneri (Le Calvez, J. & Y., 1958)

Cycloforina Luczkowska, 1972

Cycloforina quinquecarinata (Collins, 1958)

Flintina Cushman, 1921

Flintina sp. 1

Lachlanella Vella, 1957

Lachlanella sp. 1

Massilina Schlumberger, 1893

Massilina timorensis Loeblich & Tappan, 1994

Miliolina Williamson, 1858
Miliolina schlumbergeri Wiesner, 1923
Miliolinella Wiesner, 1931
Miliolinella cf M. circularis (Bornemann, 1855)
Miliolinella cf M. hybrid (Terquem, 1878)
Miliolinella cf M. hybrida Type 1 (Terquem, 1878)
Miliolinella cf M. hybrida Type 2 (Terquem, 1878)
Miliolinella cf M. hybrida Type 3 (Terquem, 1878)
Miliolinella cf M. hybrida Type 4 (Terquem, 1878)
Miliolinella chukchiensis Loeblich & Tappan, 1950
Miliolinella circularis (Bornemann, 1855)
Miliolinella fichteliana (d'Orbigny, 1839)
Miliolinella lutea (d'Orbigny, 1839)
Miliolinella oceanica (Cushman, 1932)
Miliolinella sp. 1
Miliolinella sp. 2
Miliolinella sp. 4
Miliolinella sp. 5
Miliolinella sp. 6
Miliolinella sp. 7
Miliolinella subrotunda (Montagu, 1803)
Miliolinella warreni Andersen, 1961
Pseudolachlanella Langer, 1992
Pseudolachlanella eburnea (d'Orbigny, 1839)
Pseudomassilina Lacroix, 1938
Pseudomassilina australis (Cushman, 1932)
Pseudotriloculina Cherif, 1970
Pseudotriloculina granulocostata (Germeraad, 1946)
Pseudotriloculina hottingeri Amao and Kaminski, in press
Pseudotriloculina sp. 1
Pseudotriloculina subgranulata (Cushman, 1918)
Pyrgo Defrance, 1824
Pyrgo oblonga (d'Orbigny, 1839)
Pyrgo oblonga d'Orbigny 1839: p. 163; pl. 8, figs 21-23
Pyrgo phlegeri Andersen, 1961
Pyrgo sarsi (Schlumberger, 1891)
Pyrgo sp. 2
Quinqueloculina d'Orbigny, 1826
Quinqueloculina agglutinans d'Orbigny, 1839
Quinqueloculina akneriana d'Orbigny, 1846
Quinqueloculina akneriana d'Orbigny: Cherif et al. 1997, pl. 4, figs 1, 2
Quinqueloculina bicarinata d'Orbigny, 1826
Quinqueloculina bicarinata d'Orbigny: Cherif et al. 1997, pl. 4, figs 5, 6
Quinqueloculina bidentata d'Orbigny, 1839
Quinqueloculina bosciana d'Orbigny, 1839

Quinqueloculina bosciana d'Orbigny: Haake, 1975, p. 26; pl. 1, fig. 27; pl. 5, fig. 114

Quinqueloculina cf *Q. distorqueata* Cushman, 1954

Quinqueloculina cf. *Q. stalkeri* Loeblich & Tappan, 1953

Quinqueloculina cf. *Q. buchiana* d'Orbigny, 1846

Quinqueloculina cf. *Q. myagmarsuren* Parker, 2009

Quinqueloculina cf. *Q. quinquecarinata* Collins, 1958

Cycloforina quinquecarinata (Collins, 1958)[4]

Quinqueloculina cf. *Q. subcuneata* Cushman, 1921

Quinqueloculina corrugata (Collins, 1958)

Quinqueloculina crassicarinata Collins, 1958

Quinqueloculina crassicarinata Collins, 1958: p. 359, pl. II, fig. 6.

Quinqueloculina crassicarinata Collins: Haake, 1975, p. 25; p. 1, fig. 26

Quinqueloculina erinacea Mikhalevich, 1976

Quinqueloculina impressa Reuss, 1851

Quinqueloculina impressa Reuss 185: p. 87; pl. 7 fig. 59

Quinqueloculina lamarckiana d'Orbigny, 1839

Quinqueloculina lamarckiana d'Orbigny: Haake, 1975, p. 25; pl. 1, fig. 28; pl. 2, fig. 29

Quinqueloculina limbata d'Orbigny in Fornasini, 1905

Quinqueloculina myagmarsuren Parker, 2009

Quinqueloculina parvaggluta Vella, 1957

Quinqueloculina patagonica d'Orbigny, 1839

Quinqueloculina poeyana d'Orbigny, 1839

Quinqueloculina poeyana d'Orbigny: Cherif et al. 1997, pl. 4, figs 17-2

Quinqueloculina poeyana d’Orbigny: Al-Zamel et al. 2009, fig. 8, no. 6

Quinqueloculina rebeccae Vella, 1957

Quinqueloculina rebeccae Vella, 1957: p. 25; pl. 5, figs 84-85, 88

Quinqueloculina schlumbergeri (Wiesner, 1923)

Quinqueloculina seminula (Linnaeus, 1758)

Quinqueloculina sp. 1

Quinqueloculina sp. 2

Quinqueloculina sp. 3

Quinqueloculina sp. 4

Quinqueloculina sp. 5

Quinqueloculina sp. 6

Quinqueloculina sp. 7

Quinqueloculina sp. 8

Quinqueloculina sp. 9

Quinqueloculina sp. 10

Quinqueloculina sp. 11

Quinqueloculina sp. 12

Quinqueloculina sp. 13

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[4] Original accepted name based on WoRMS database (http://www.marinespecies.org/aphia.php?p=taxdetails&id=489138)

Quinqueloculina sp. 14
Quinqueloculina sp. 15
Quinqueloculina sp. 16
Quinqueloculina sp. 17
Quinqueloculina sp. 18
Quinqueloculina sp. 19
Quinqueloculina sp. 20
Quinqueloculina sp. 21
Quinqueloculina sp. 22
Quinqueloculina sp. 23
Quinqueloculina sp. 24
Quinqueloculina sp. 25
Quinqueloculina sp. 26
Quinqueloculina sp. 27
Quinqueloculina sp. 28
Quinqueloculina sp. 29
Quinqueloculina sp. 30
Quinqueloculina sp. 31
Quinqueloculina sp. 32
Quinqueloculina sp. 33
Quinqueloculina sp. 34
Quinqueloculina sp. 35
Quinqueloculina sp. 36
Quinqueloculina sp. 37
Quinqueloculina sp. 38
Quinqueloculina sp. 39
Quinqueloculina sp. 40
Quinqueloculina sp. 41
Quinqueloculina sp. 42
Quinqueloculina sp. 43
Quinqueloculina sp. 44
Quinqueloculina stalkeri Loeblich & Tappan, 1953
Quinqueloculina subcuneata Cushman, 1921
Quinqueloculina subpolygona Parr, 1945

Sigmamiliolinella Zheng, 1988

Sigmamiliolinella australis (Parr, 1932)
Sigmamiliolinella sp. 1

Sigmoilina Schlumberger, 1887

Sigmoilina sp. 1

Sigmoilopsis Finlay, 1947

Sigmoilopsis cf. *S. herzensteini* Schlumberger, 1894
Sigmoilopsis elliptica (Galloway & Wissler, 1927)
Sigmoilopsis sp. 1
Sigmoilopsis sp. 2
Sigmoilopsis sp. 3

Sigmoilopsis sp. 4

Siphonaperta Vella, 1957

Siphonaperta cf. *S. agglutinans*
Siphonaperta cf. *S. horrida*
Siphonaperta pittensis (Albani, 1974)
Siphonaperta sp. 1
Siphonaperta sp. 2
Siphonaperta sp. 3
Siphonaperta sp. 4
Siphonaperta sp. 5
Siphonaperta sp. 6

Triloculina d'Orbigny, 1826

Triloculina cf. *T. serrulata* McCulloch, 1977
Triloculina aff. *T. vespertilio* Zheng, 1988
Triloculina cf. *T. tricarinata* d'Orbigny, 1826
Triloculina cf. *T. affinis* d'Orbigny, 1852
Triloculina cf. *T. asymmetrica* Said, 1949
    Triloculinella asymmetrica (Said, 1949)[5]
Triloculina cf. *T. fichteliana* d'Orbigny, 1839
    Miliolinella fichteliana (d'Orbigny, 1839)[6]
Triloculina elongotricarinata Debenay, 2013
Triloculina frigida Lagoe, 1977
Triloculina marioni Schlumberger, 1893
    Triloculina marioni Schlumberger: Haake 1975, p. 39; pl. 4, fig. 91
Triloculina plicata Terquem, 1878
Triloculina quadrata Collins, 1958
Triloculina serrulata McCulloch, 1977
    Triloculina serrulata McCulloch 1977: p. 558; pl. 225, figs 1, 2, 4
Triloculina sp. 1
Triloculina sp. 2
Triloculina sp. 3
Triloculina sp. 4
Triloculina sp. 5
Triloculina sp. 6
Triloculina sp. 7
Triloculina sp. 8
Triloculina sp. 9
Triloculina sp. 10
Triloculina sp. 11
Triloculina sp. 12
Triloculina terquemiana (Brady, 1884)

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[5] Original accepted name based on WoRMS database (http://www.marinespecies.org/aphia.php?p=taxdetails&id=490006)

[6] Original accepted name based on WoRMS database (http://www.marinespecies.org/aphia.php?p=taxdetails&id=417687)

Triloculina terquemiana (Brady 1884): p. 166; pl. 144, fig. 1a, b
Triloculina terquemiana (Brady): Haake 1975, p. 39; pl. 5, fig. 93
Triloculina tricarinata d'Orbigny, 1826
Triloculina tricarinata d'Orbigny, 1826: p. 299
Triloculina tricarinata d'Orbigny: Haake 1975, p. 38; pl. 4, figs 82-86
Triloculina tricarinata d'Orbigny: Cherif et al. 1997, pl. 5, figs 15, 16
Triloculina trigonula (Lamarck, 1804)
Triloculina trihedra Loeblich & Tappan, 1953
Triloculinella Riccio, 1950
Triloculinella asymmetrica (Said, 1949)
Triloculinella chiastocytis Loeblich & Tappan, 1994
Triloculinella chiastocytis Loeblich & Tappan, 1994: p. 57; pl 97, figs 7-9; pl. 98, figs 4-6, 1-18
Hauerinidae Schwager, 1876
Adelosina d'Orbigny, 1826
Adelosina carinatastriata (Wiesner, 1923)
Miliolidae Ehrenberg, 1839
Edentostomina Collins, 1958
Edentostomina rupertiana (Brady, 1881)
Spiroloculinidae Wiesner, 1920
Massilina Schlumberger, 1893
Massilina laevigata (Cushman & Todd, 1944)
Naxotia Al-Zamel & Cherif, 1997
Naxotia attenuata (Cushman & Todd, 1944)
Spiroloculina d'Orbigny, 1826
Spiroloculina aff *S. indica* Cushman & Todd, 1944
Spiroloculina aff. *S. communis* Cushman & Todd, 1944
Spiroloculina antillarum d'Orbigny, 1839
Spiroloculina antillarum d'Orbigny 1839: p. 166; pl. 9, figs 3, 4
Spiroloculina cf. *S. carinata* Fornasini, 1905
Spiroloculina cf *S. nummiformis* Said, 1949
Spiroloculina cf. *S. communis* Cushman & Todd, 1944
Spiroloculina cf. *S. depressa* d'Orbigny, 1826
Spiroloculina communis Cushman & Todd, 1944
aff. *Spiroloculina communis* Cushman & Todd 1944: p. 63; pl. 9, figs 4, 5, 7, 8
Spiroloculina elegantissima Said, 1949
Spiroloculina excavata d'Orbigny, 1846
Spiroloculina excavata d'Orbigny 1839: p. 271; pl. 16, figs 19-21
Spiroloculina excavata d'Orbigny: Cherif et al. 1997, pl. 2, figs 17, 18
Spiroloculina hadai Thalmann, 1933
Spiroloculina hadai Thalmann: Haake 1975, p. 2; pl. 1, fig. 13
Spiroloculina indica Cushman & Todd, 1944
Spiroloculina nummiformis Said, 1949
Spiroloculina nummiformis Said, 1949: p.16; pl. 1, fig. 39
Spiroloculina nummiformis Said: Cherif et al. 1997, pl. 2, figs 23-26

Spiroloculina pulchella d'Orbigny in Fornasini, 1904
Spiroloculina regularis Cushman & Todd, 1944
Spiroloculina rotunda d'Orbigny, 1826
Spiroloculina rotundata (Williamson): Cherif et al. 1997, pl. 2, figs 21, 22
Spiroloculina rotundata Williamson: Al-Zamel et al. 2009, fig. 8, no. 3
Pseudotriloculina rotunda (Schlumberger, 1893)[7]
Spiroloculina sp. 1
Spiroloculina sp. 2
Spiroloculina sp. 3
Spiroloculina sp. 4
Spiroloculina sp. 5
Spiroloculina sp. 6
Spiroloculina sp. 7
Spiroloculina sp. 8
Spiroloculina sp. 9
Spiroloculina sp. 10
Spiroloculina sp. 11
Spiroloculina sp. 12
Spiroloculina sp. 13
Spiroloculina sp. 14
Spiroloculina sp. 15
Spiroloculina sp. 16
Spiroloculina subimpressa Parr, 1950
Nubecularioidea
Fischerinidae Millett, 1898
Vertebralina d'Orbigny, 1826
Vertebralina striata d'Orbigny, 1826
Vertebralina striata d'Orbigny 1826: p. 283
Wiesnerella Cushman, 1933
Wiesnerella auriculata (Egger, 1893)
Wiesnerella auriculata (Egger, 1893): Haake 1975, p. 2; pl. 1, fig. 7
Nubeculariidae Jones, 1875
Nubeculina Cushman, 1924
Nubeculina sp. 1
Pseudonubeculina Amao and Kaminski 2016
Pseudonubeculina arabica Amao and Kaminski 2016
Pseudonubeculina sp. 1
Ophthalmidiidae Wiesner, 1920
Edentostomina Collins, 1958
Edentostomina cultrata (Brady, 1881)
Edentostomina sp. 1
Ophthalmidium Kubler & Zwingli, 1870
Ophthalmidium sp. 1

[7] Original accepted name based on WoRMS database (http://www.marinespecies.org/aphia.php?p=taxdetails&id=112578)

Soritoidea Ehrenberg, 1839
Peneroplidae Schultze, 1854
Coscinospira Ehrenberg, 1839
Coscinospira arietina (Batsch, 1791)
Coscinospira hemprichii Ehrenberg, 1839
Coscinospira sp. 1
Peneroplis de Montfort, 1808
Peneroplis pertusus (Forskål, 1775)
Peneroplis pertusus (Forskål, 1775): Cherif et al. 1997, pl. 6, figs 5, 6
Soritidae Ehrenberg, 1839
Sorites Ehrenberg, 1839
Sorites orbiculus (Forskål, 1775)
Rotaliida Delage & Hérouard, 1896
Acervulinoidea Schultze, 1854
Acervulinidae Schultze, 1854
Acervulina Schultze, 1854
Acervulina cf. *A. mabahethi* (Said, 1949)
Acervulina sp. 01
Gypsina Carter, 1877
Gypsina sp. 1
Asterigerinoidea d'Orbigny, 1839
Amphisteginidae Cushman, 1927
Amphistegina d'Orbigny, 1826
Amphistegina lessonii d'Orbigny in Guérin-Méneville, 1832
Amphistegina lessonii d'Orbigny, 1826: p. 34
Amphistegina lessonii (d'Orbigny): Cherif et al. 1997, pl. 8, figs 5, 6
Amphistegina papillosa Said, 1949
Bolivinitoidea Cushman, 1927
Bolivinitidae Cushman, 1927
Fursenkoina Loeblich & Tappan, 1961
Fursenkoina sp. 1
Fursenkoina sp. 2
Fursenkoina sp. 3
Fursenkoina sp. 4
Loxostomina Sellier de Civrieux, 1969
Loxostomina costulata (Cushman, 1922)
Loxostomina sp. 01
Loxostomina sp. 02
Pseudobrizalina Zweig-Strykowski & Reiss, 1976
Pseudobrizalina lobata (Brady, 1881)
Sagrinella Saidova, 1975
Sagrinella sp. 1
Sigmavirgulina Loeblich & Tappan, 1957
Sigmavirgulina sp. 1
Sigmavirgulina sp. 2

Sigmavirgulina sp. 3
Sigmavirgulina sp. 4
Bolivinoidea Glaessner, 1937
Bolivinidae Glaessner, 1937
Bolivina d'Orbigny, 1839
Bolivina cf *B. persiensis* Lutze, 1974
Bolivina cf. *B. plicata* d'Orbigny, 1839
Bolivina cf. *B. striatula* Cushman, 1922
Bolivina cf. *B. suezensis* Said, 1949
Bolivina striatula Cushman, 1922
Bolivinellina Saidova, 1975
Bolivinellina cf. *B. translucens* Phleger & Parker, 1951
Brizalina Costa, 1856
Brizalina cf. *B. subspathulata* (Boomgaart, 1949)[8]
Bolivina dilatata Reuss, 1850
Brizalina sp. 1
Buliminoidea Jones, 1875
Buliminidae Jones, 1875
Bulimina d'Orbigny, 1826
Bulimina biserialis Millett, 1900
Bulimina cf. *B. marginata* d'Orbigny, 1826
Bulimina marginata d'Orbigny, 1826
Bulimina sp. 1
Bulimina sp. 2
Bulimina sp. 3
Bulimina sp. 4
Bulimina sp. 5
Bulimina sp. 6
Reussellidae Cushman, 1933
Reussella Galloway, 1933
Reussella pulchra Cushman, 1945
Reussella sp. 1
Reussella sp. 2
Reussella sp. 3
Reussella sp. 4
Reussella sp. 5
Trimosinidae Saidova, 1975
Trimosina Cushman, 1927
Trimosina cf *T. milletti multispinata* Cushman, 1927
Uvigerinidae Haeckel, 1894
Siphouvigerina Parr, 1950
Siphouvigerina proboscidea (Schwager, 1866)
Uvigerina d'Orbigny, 1826

[8] Original accepted name based on WoRMS database http://www.marinespecies.org/aphia.php?p=taxdetails&id=112973

Uvigerina cf. *U. peregrina* Cushman, 1923

Chilostomelloidea Brady, 1881

Anomalinidae Cushman, 1927

Cibicidoides Thalmann, 1939

Cibicidoides sp. 1

Cibicidoides sp. 2

Hanzawaia Asano, 1944

Hanzawaia asterizans (Fichtel & Moll, 1798)

Hanzawaia cf. *H. nipponica* Asano, 1944

Hanzawaia sp. 1

Hanzawaia sp. 2

Hanzawaia sp. 3

Hanzawaia sp. 4

Hanzawaia sp. 5

Hanzawaia sp. 6

Discorboidea Ehrenberg, 1838

Cancrisidae Chapman, Parr & Collins, 1934

Cancris de Montfort, 1808

Cancris auriculus (Fichtel & Moll, 1798)

Cancris bubnanensis (McCulloch, 1977)

Cancris cf. *C. bubnanensis* (McCulloch, 1977)

Cancris cf. *C. oblongus*

Cancris cf. *C. auriculus* (Fichtel & Moll, 1798)

Cancris sp. 1

Cancris sp. 2

Discorbidae Ehrenberg, 1838

Gavelinopsis Hofker, 1951

Gavelinopsis cf. *G. praegeri* (Heron-Allen & Earland, 1913)

Eponididae Hofker, 1951

Eponides de Montfort, 1808

Eponides sp. 1

Rosalinidae Reiss, 1963

Rosalina d'Orbigny, 1826

Rosalina adhaerens Murray 1965

Rosalina adhaerens Murray, 1965: p. 77, pl. III, figs 1-8.

Rosalina bradyi (Cushman, 1915)

Rosalina pellucida (Said, 1949)

Rosalina sp. 1

Rosalina sp. 2

Rosalina sp. 3

Rosalina sp. 4

Rosalina sp. 5

Rosalina sp. 6

Rosalina sp. 7

Rosalina sp. 8

Rosalina sp. 9
Rosalina sp. 10
Rosalina sp. 11
Glabratelloidea Loeblich & Tappan, 1964
Glabratellidae Loeblich & Tappan, 1964
Glabratella Dorreen, 1948
Glabratella sp. 1
Glabratellina Seiglie & Bermúdez, 1965
Glabratellina sp. 1
Nonionoidea Schultze, 1854
Nonionidae Schultze, 1854
Nonion de Montfort, 1808
Nonion cf. *N. depressulus* Walker & Jacob, 1798
Haynesina depressula (Walker & Jacob, 1798)[9]
Nonion sp. 1
Nonion sp. 2
Nonion sp. 3
Nonion sp. 4
Nonion sp. 5
Nonionella Rhumbler, 1949
Nonionella cf. *N. grateloupi* (d'Orbigny, 1839)
Nonionoides grateloupii (d'Orbigny, 1839)[10]
Nonionella cf. *N. iridea* Heron-Allen & Earland, 1932
Nonionella pulchella Hada, 1931
Nonionellina Voloshinova, 1958
Nonionellina cf. *N. labradorica* (Dawson, 1860)
Nonionoides Saidova, 1975
Nonionoides grateloupii (d'Orbigny, 1839)
Pseudononion Asano, 1936
Pseudononion japonicum Asano, 1936
Nummulitoidea Blainville, 1827
Nummulitidae de Blainville, 1827
Operculina d'Orbigny, 1826
Operculina ammonoides Sidebottom, 1918
Operculina sp. 1
Operculina sp. 2
Nummulitidae de Blainville, 1827
Assilina d'Orbigny, 1839
Assilina sp. 1
Planorbulinoidea Schwager, 1877
Cibicididae Cushman, 1927

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[9] Original accepted name based on WoRMS database (http://www.marinespecies.org/aphia.php?p=taxdetails&id=113293)
[10] Original accepted name based on WoRMS database (http://www.marinespecies.org/aphia.php?p=taxdetails&id=418051)

Cibicides de Montfort, 1808
Cibicides cf. *C. phillipensis* Collins, 1974
Cibicides cf. *C. refulgens* de Montfort, 1808
Cibicides cf. *C. tabaensis* Perelis & Reiss, 1975
Cibicides sp. 1
Cibicides sp. 2
Cibicides sp. 3
Cibicides sp. 4
Cibicides sp. 5
Cibicides sp. 6
Lobatula Fleming, 1822
Lobatula lobatula (Walker & Jacob, 1798)
Lobatula sp. 1
Cymbaloporidae Cushman, 1927
Cymbaloporetta Cushman, 1928
Cymbaloporetta cf. *C. bradyi* Cushman, 1915
Cymbaloporetta sp. 1
Cymbaloporetta sp. 2
Cymbaloporetta sp. 3
Cymbaloporetta sp. 4
Cymbaloporetta sp. 5
Cymbaloporetta sp. 6
Millettiana Banner, Pereira & Desai, 1985
Millettiana millettii (Heron-Allen & Earland, 1915)
Planorbulinidae Schwager, 1877
Planorbulina d'Orbigny, 1826
Planorbulina sp. 1
Rotalioidea Ehrenberg, 1839
Elphidiidae Galloway, 1933
Cribroelphidium Cushman & Brönnimann, 1948
Cribroelphidium poeyanum (d'Orbigny, 1826)
Cribroelphidium poeyanum (d’Orbigny, 1826): Cherif et al. 1997, pl. 10, figs 6, 7
Cribroelphidium poeyanum (d’Orbigny, 1826): Al-Zamel et al. 2009, fig. 8, no. 11
Cribroelphidium sp. 1
Cribroelphidium sp. 2
Elphidium de Montfort, 1808
Elphidium advenum (Cushman, 1922)
Elphidium advenum (Cushman, 1922): Lutze 1974, p. 31; pl. 8, figs 119-121
Elphidium advenum subsp. *macelliforme* McCulloch, 1981
Elphidium advenum (Cushman, 1922): Lutze 1974, p. 31; pl. 8, figs 119-121
Elphidium cf. *E. advenum* (Cushman, 1922)
Elphidium cf. *E. gerthi* Van Voorthuysen, 1957
Elphidium cf. *E. neosimplex* McCulloch, 1977
Elphidium craticulatum (Fichtel & Moll, 1798)

Elphidium fichtellianum (d'Orbigny, 1846)
Elphidium gerthi Van Voorthuysen, 1957
Elphidium hawkesburyense (Albani, 1974)
Elphidium hispidulum Cushman, 1936
Elphidium maorium Hayward, 1997
Elphidium neosimplex McCulloch, 1977
Elphidium reticulosum Cushman, 1933
Elphidium reticulosum Cushman, 1933: p. 51; pl. 12, fig. 5
Elphidium sp. 1
Elphidium sp. 3
Elphidium striatopunctatum (Fichtel & Moll, 1798)
Elphidium tongaense (Cushman, 1931)
Rotaliidae Ehrenberg, 1839
Ammonia Brünnich, 1772
Ammonia aoteana (Finlay, 1940)
Ammonia cf. *A. aberdoveyensis* Haynes, 1973
Ammonia cf. *A. convexa* (Collins, 1958)
Ammonia cf. *A. faceta* He, Hu & Wang, 1965
Ammonia cf. *A. parkinsoniana* (d'Orbigny, 1839)
Ammonia cf. *A. tepida* (Cushman, 1926)
Ammonia convexa Collins, 1958
Ammonia falsobeccarii (Rouvillois, 1974)
Ammonia sp. 1
Ammonia sp. 2
Ammonia sp. 3
Ammonia tepida (Cushman, 1926)
Ammonia tepida Cushman 1926: p. 79; pl. 1
Rotaliidae Ehrenberg, 1839
Asterorotalia Hofker, 1950
Asterorotalia dentata (Parker & Jones, 1865)
Asterorotalia dentata (Parker & Jones, 1865): Lutze 1974, p. 3; pl. 7, fig. 116
Asterorotalia dentata (Parker & Jones, 1865): Billmann, Hottinger & Oesterle, 1980, p. 96; pl. 14, fig. 7
Asterorotalia dentata (Parker & Jones, 1865): Lutze 1974, p. 3; pl. 7, figs 117, 118
Asterorotalia inflate (Millett, 1904)
Asterorotalia inflata (Millett, 1904): Lutze 1974, p. 31
Asterorotalia pulchella (d'Orbigny, 1839)
Asterorotalia trispinosa (Thalmann, 1933)
Asterorotalia sp. 1
Asterorotalia sp. 2
Asterorotalia sp. 3
Asterorotalia sp. 4
Asterorotalia sp. 5
***Challengerella* Billman, Hottinger & Oesterle, 1980**

Challengerella cf. *C. persica* Bilman, Hottinger & Oesterle, 1980
Challengerella persica Bilman, Hottinger & Oesterle, 1980
Challengerella persica Billmann, Hottinger & Oesterle, 1980: p. 91; pl. 13, figs 1-15; pl. 15, figs 1-6
Challengerella persica Billmann, Hottinger & Oesterle, 1980: Cherif et al. 1997, pl. 1, figs 1-4
Challengerella sp. 1
Rotalinoides Saidova, 1975
Rotalinoides gaimardii (d'Orbigny, 1826)
Rotalioidea Ehrenberg, 1839
Elphidiidae Galloway, 1933
Cristatavultus Loeblich & Tappan, 1994
Cristatavultus milletti (Heron-Allen & Earland, 1915)
Spirillinida Hohenegger & Piller, 1975
Spirillinidae Reuss & Fritsch, 1861
Spirillina Ehrenberg, 1843
Spirillina sp. 1
Spirillina sp. 2
Textulariida Delage & Hérouard, 1896
Eggerelloidea Cushman, 1937
Valvulinidae Berthelin, 1880
Clavulina d'Orbigny, 1826
Clavulina angularis d'Orbigny, 1826
Clavulina sp. 1
Olgia Mikhalevich, 2011
Olgia pacifica (Cushman, 1924)
Textularioidea Ehrenberg, 1838
Textulariidae Ehrenberg, 1838
Bigenerina d'Orbigny, 1826
Bigenerina sp. 1
Dorothia Plummer, 1931
Dorothia goesi (Cushman, 1911)
Sahulia Loeblich & Tappan, 1985
Sahulia barkeri (Hofker, 1978)
Sahulia barkeri (Hofker, 1978): Cherif et al. 1997, pl. 1, figs 4, 5
Sahulia cf. *S barkeri* (Hofker, 1978)
Sahulia conica (d'Orbigny, 1839)
Sahulia kerimbaensis (Said, 1949)
Sahulia sp. 1
Sahulia sp. 2
Spirotextularia Saidova, 1975
Spirotextularia cf. *S. floridana* (Cushman, 1922)
Siphotextularia Finlay, 1939
Siphotextularia heterostoma (Fornasini, 1896)
Textularia Defrance, 1824

Textularia earlandi Parker, 1952
Textularia bocki Höglund, 1947
Textularia cf. *T. conica* (d'Orbigny, 1839)
    Sahulia conica (d'Orbigny, 1839)[11]
Textularia cf. *T. foliacea* Heron-Allen & Earland, 1915
Textularia cf. *T. foliacea occidentalis* Cushman, 1932
    Textularia occidentalis Cushman, 1922[12]
Textularia cf. *T. stricta* Cushman, 1911
Textularia cushmani Said, 1949
    Textularia cushmani Said 1949: p. 7, pl. 1, fig. 13 a, b
Textularia foliacea Heron-Allen & Earland, 1915
    Textularia foliacea Heron-Allen & Earland 1915: p. 628; pl. 47, figs 17-2
Textularia foliacea oceanica Cushman, 1932
    Textularia oceanica Cushman, 1932[13]
Textularia pala Czjzek, 1848
Textularia sp. 1
Textularia sp. 2
Textularia sp. 3
Textularia sp. 4
Textularia sp. 5
Textularia sp. 6
Textularia sp. 7
Textularia sp. 8
Textularia sp. 9
Textularia sp. 10
Textularia sp. 11
Textularia sp. 12
Textularia sp. 13
Textularia sp. 14
Textularia sp. 15
Textularia sp. 16
Textularia sp. 17
Textularia sp. 18
Textularia sp. 19
Textularia sp. 20
Textularia sp. 21

[11] Original accepted name based on WoRMS database http://www.marinespecies.org/aphia.php?p=taxdetails&id=114253
[12] Original accepted name based on WoRMS database http://www.marinespecies.org/aphia.php?p=taxdetails&id=723334
[13] Original accepted name based on WoRMS database http://www.marinespecies.org/aphia.php?p=taxdetails&id=491929

PLATES

PLATE 01 ((?) ***Agglutinated sp* –** (?) ***Clavulina angularis)***

a–b (?) ***Agglutinated* sp. 1** (a) & (b) lateral views.

c–e ***Thurammina papyracea*** (c) peripheral view of the opposite side (d) & (e).

f–h ***Haplophragmoides pusillus*** (f) apertural view (g) & (h) lateral views.

i–k ***Trochammina inflata*** (i) apertural view (j) spiral view (k) umbilical view.

l–n ***Migros* cf. M. *flintini*** (l) peripheral view (m) lateral view (n) lateral view of the opposite side.

o–q ***Migros* cf. M. *flintini*** (o) apertural view (p) lateral view (q) lateral view of the opposite side.

r–t (?) ***Lagenammina* sp.** (r) peripheral view (s) lateral view (t) lateral view of the opposite side.

u–w (?) ***Clavulina angularis*** (u) apertural view (v) lateral view (w) lateral view of the opposite side.

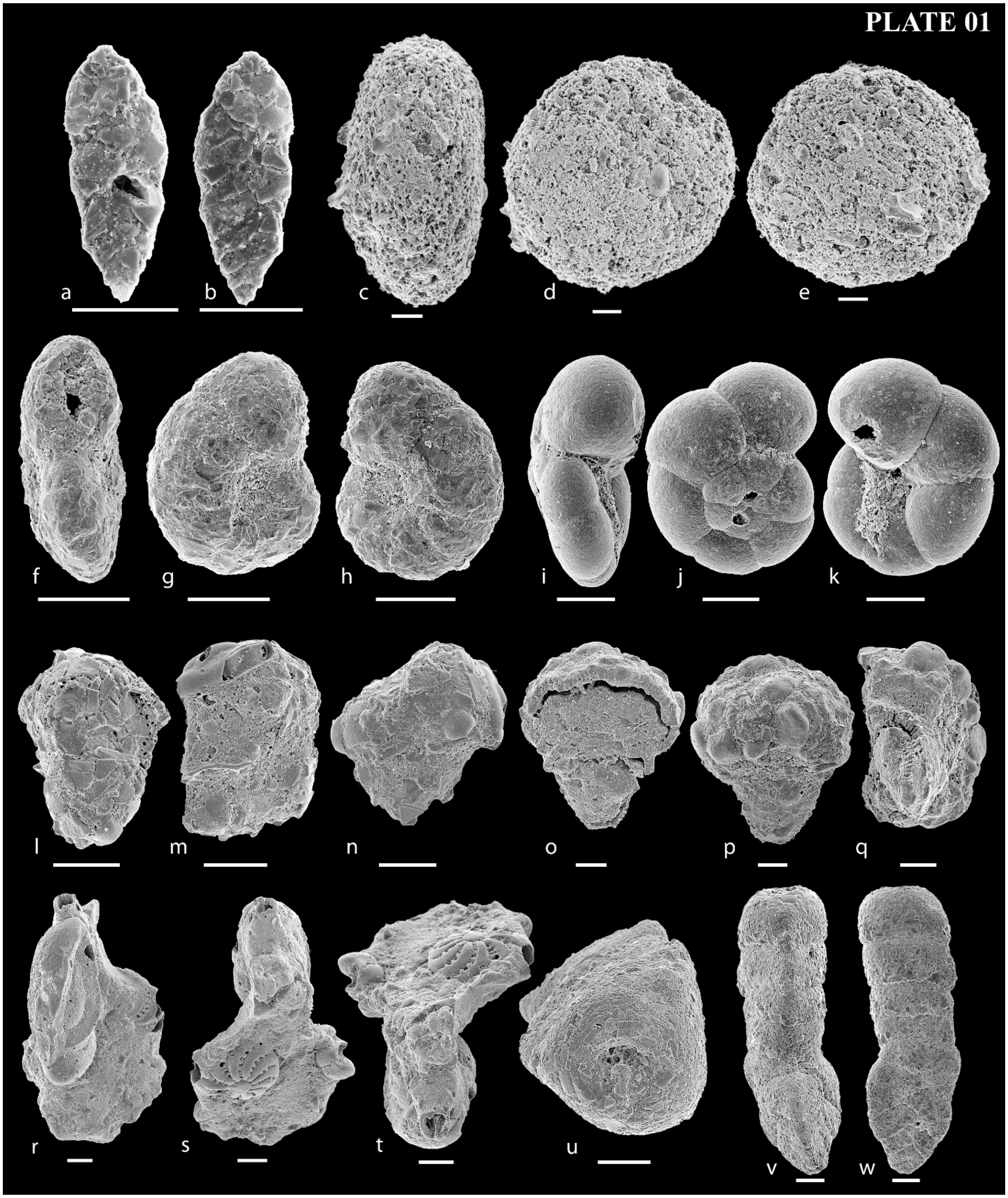
PLATE 01
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PLATE 02 (Gaudryina *convexa* – *Gaudryina* sp. 06)

a–c ***Gaudriyina convexa*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Gaudryina* sp. 01** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Gaudryina* sp. 02** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–k ***Gaudryina* sp. 03** (j) apertural view (k) lateral view.

l–n ***Gaudryina attenuata*** (l) apertural view (m) lateral view (n) lateral view of the opposite side.

o–q ***Gaudryina* sp. 04** (o) apertural view (p) lateral view (q) lateral view of the opposite side.

r–t ***Gaudryina* sp. 05** (r) apertural view (s) lateral view (t) posterior view.

u–w ***Gaudryina* sp. 06** (u) apertural view (v) lateral view (w) lateral view of the opposite side.

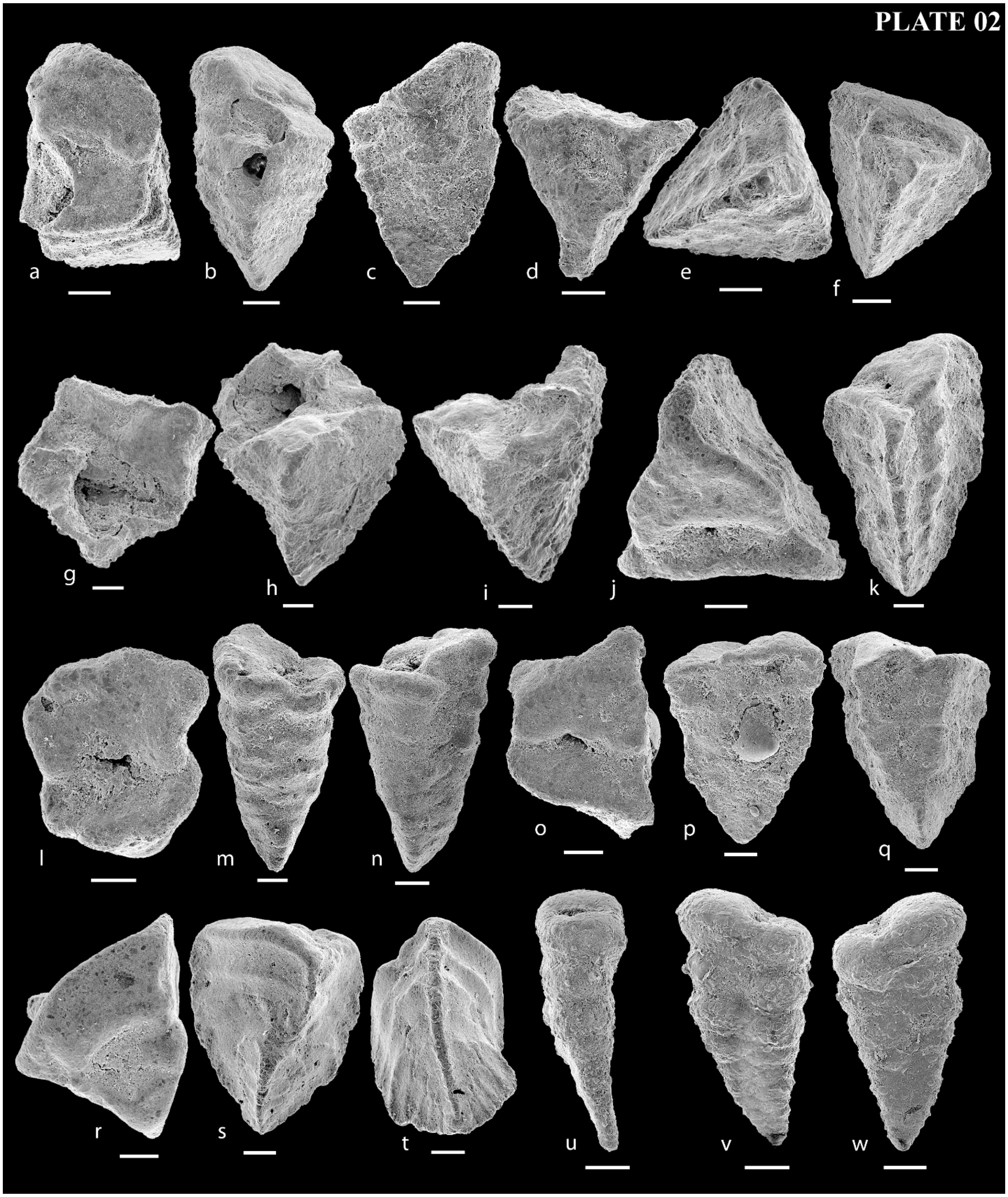
PLATE 02
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PLATE 03 (*Textularia* sp. 26 – *Textularia* sp. 23)

a–c ***Textularia* sp. 26** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Textularia* sp. 24** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Textularia* sp. 22** (g) apertural view (h) lateral view (i) posterior view.

j–l ***Textularia* sp. 25** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Textularia* sp. 27** (m) apertural view (n) lateral view (o) posterior view.

p–r ***Textularia* sp. 21** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Textularia* sp. 28** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Textularia* sp. 23** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

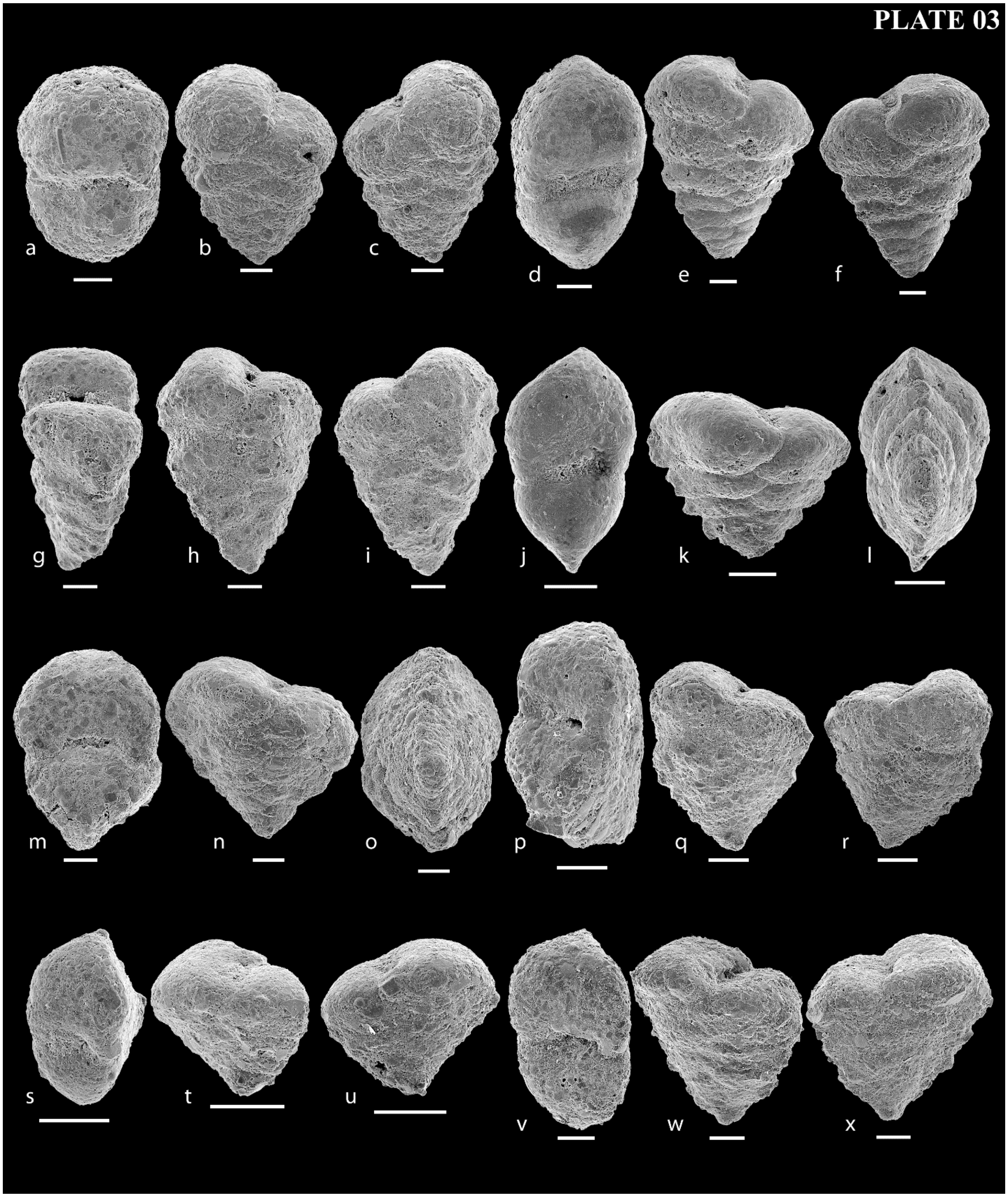
PLATE 03
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PLATE 04 (*Textularia conica* – *Textularia* sp. 18)

a–c ***Textularia conica*** (a) apertural view (b) posterior view (c) lateral view of the opposite side.

d–f ***Sahulia barkeri*** (d) apertural view (e) posterior view (f) lateral view.

g–i ***Sahulia* cf. *S. barkeri*** (g) apertural view (h) lateral view (i) posterior view.

j–l ***Sahulia* cf. *S. barkeri*** (j) apertural view (k) posterior view (l) lateral view.

m–o ***Sahulia* cf. *S. barkeri*** (m) apertural view (n) posterior view (o) lateral view.

p–r ***Textularia* sp. 19** (p) apertural view (q) lateral view (r) posterior view.

s–u ***Textularia* sp. 20** (s) apertural view (t) lateral view (u) posterior view.

v–x ***Textularia* sp. 18** (v) apertural view (w) lateral view (x) lateral view of the opposite side.


PLATE 04
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PLATE 05 (*Spiroplectinella sagittula – Textularia pala)*

a–c ***Spiroplectinella sagittula*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Textularia* sp. 17** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Textularia goessi*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Textularia* sp. 16** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Textularia* cf *T. kerimbaensis*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Textularia kerimbaensis*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Textularia pala*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Textularia pala*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

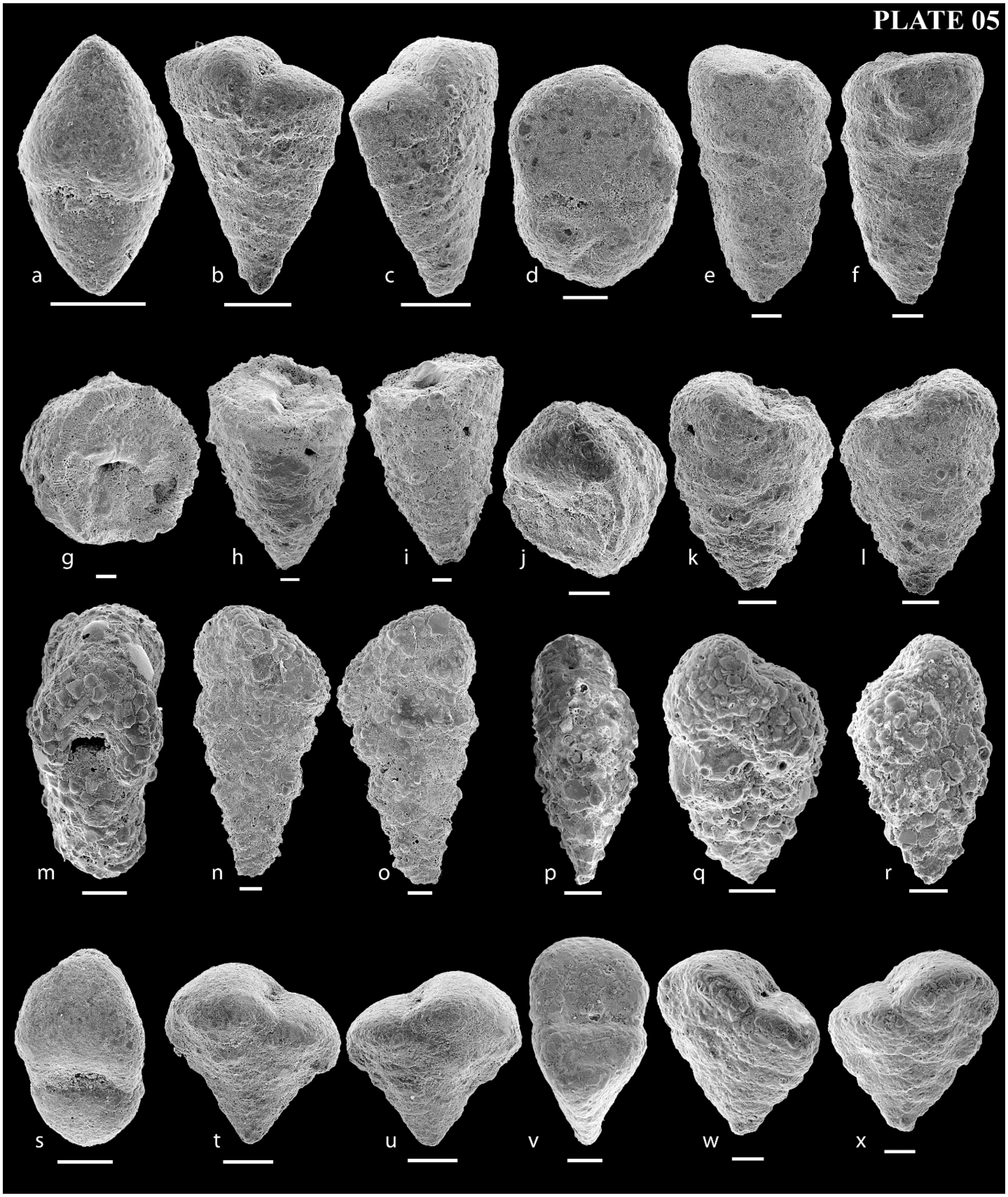
PLATE 05
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PLATE 06 (*Spiroplectammina earlandi – Textularia* cf. *T. foliacea)*

a–c ***Spiroplectammina earlandi*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Spiroplectammina earlandi*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Textularia* sp. 15** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Textularia* sp. 08** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Textularia* sp. 07** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Textularia* sp. 04** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Textularia* sp. 06** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Textularia* cf. *T. foliacea*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

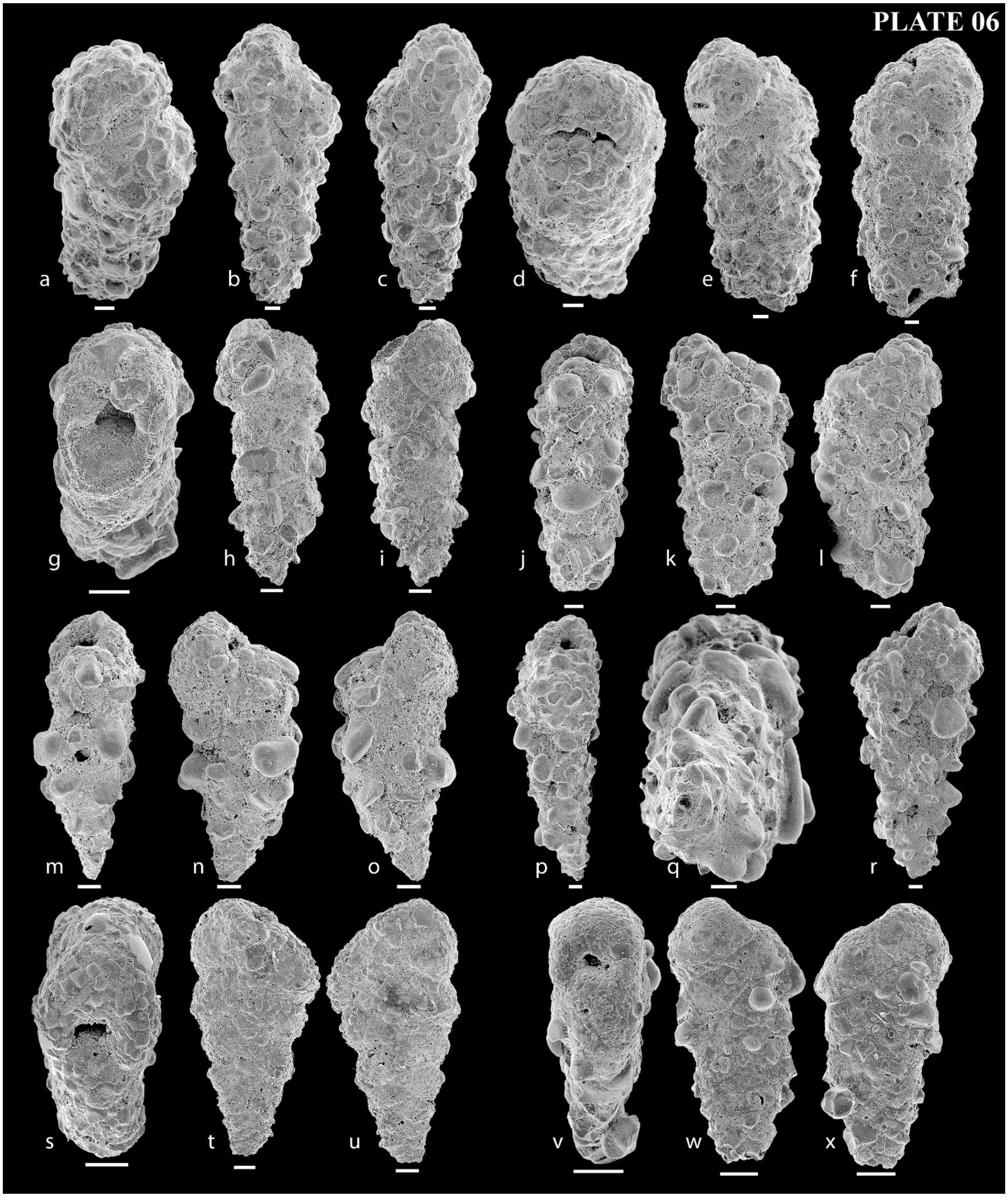
PLATE 06
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PLATE 07 (*Spiroplectammina earlandi* – *Textularia* cf. *T. foliacea)*

a–c ***Spiroplectammina earlandi*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Textularia* sp. 10 *(***d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Textularia* sp. 05** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Textularia* sp. 09** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Textularia* sp. 14** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Textularia* cf. *T. foliacea*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

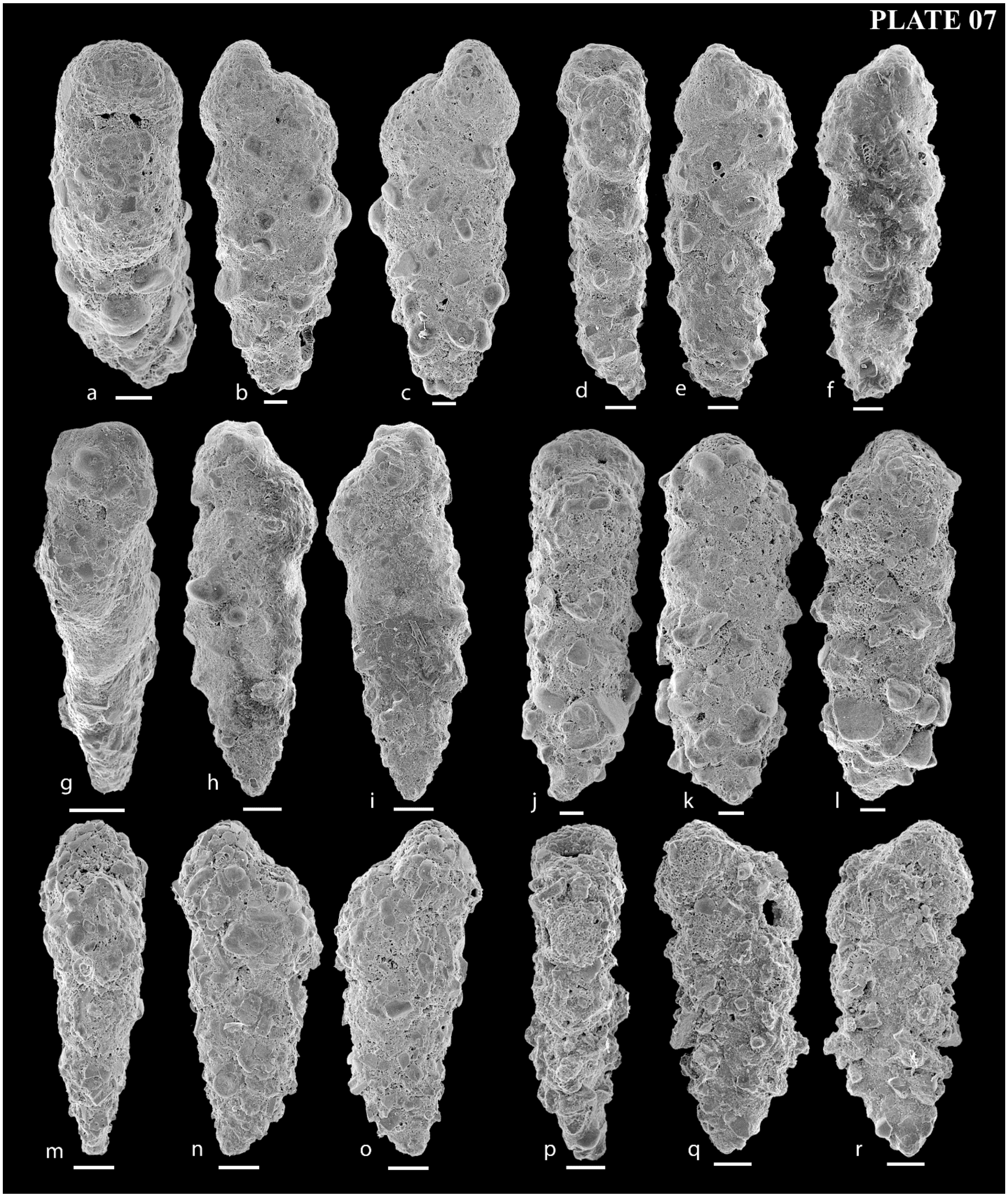
PLATE 07
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PLATE 08 (*Spirotextularia* cf. *S. floridana* – *Spirotextularia* cf. *S. floridana)*

a–c ***Spirotextularia* cf. *S. floridana*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Spirotextularia* cf. *S. floridana (***d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Textularia stricta*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Textularia stricta*** (j) peripheral view (k) lateral view (l) lateral view of the opposite side.

m–o ***Spirotextularia* cf. *S. floridana*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Spirotextularia* cf. *S. floridana*** (p) peripheral view (q) lateral view (r) lateral view of the opposite side.


PLATE 08
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PLATE 09 (*Textularia* sp. 12 – *Textularia* sp. 13)

a–c ***Textularia* sp. 12** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Textularia foliacea*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Textularia* cf. *T. foliacea occidentalis*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Textularia cushmani*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Textularia foliacea*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Textularia* sp. 01** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Textularia* sp. 03** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Textularia* sp. 13** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

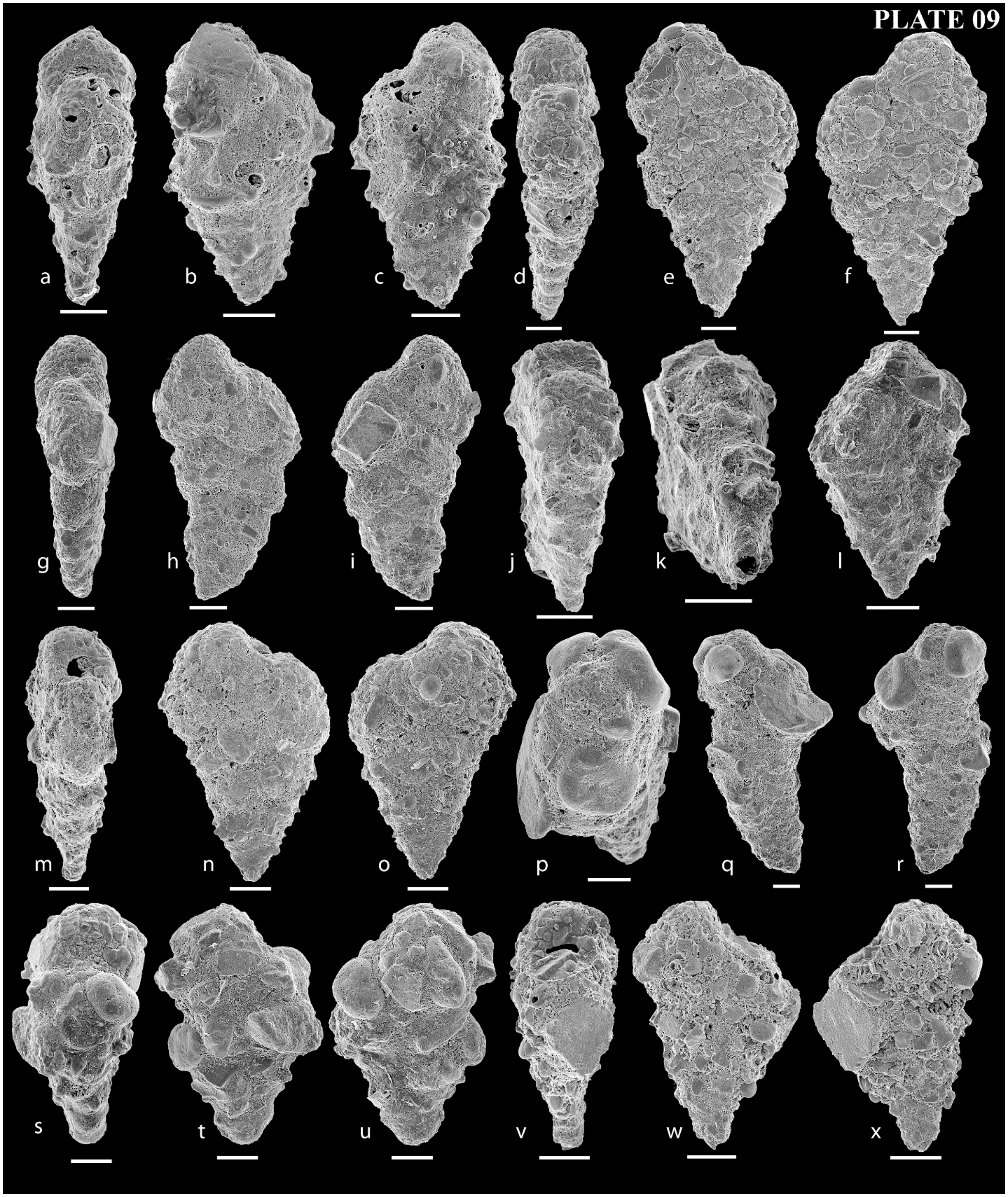
PLATE 09
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PLATE 10 (Textularia *foliacea oceanica* – *Textularia* sp. 11)

a–c ***Textularia foliacea oceanica*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Textularia foliacea oceanica*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Textularia* cf. *T. foliacea occidentalis*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Textularia* sp. 02** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Textularia* sp. 11** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

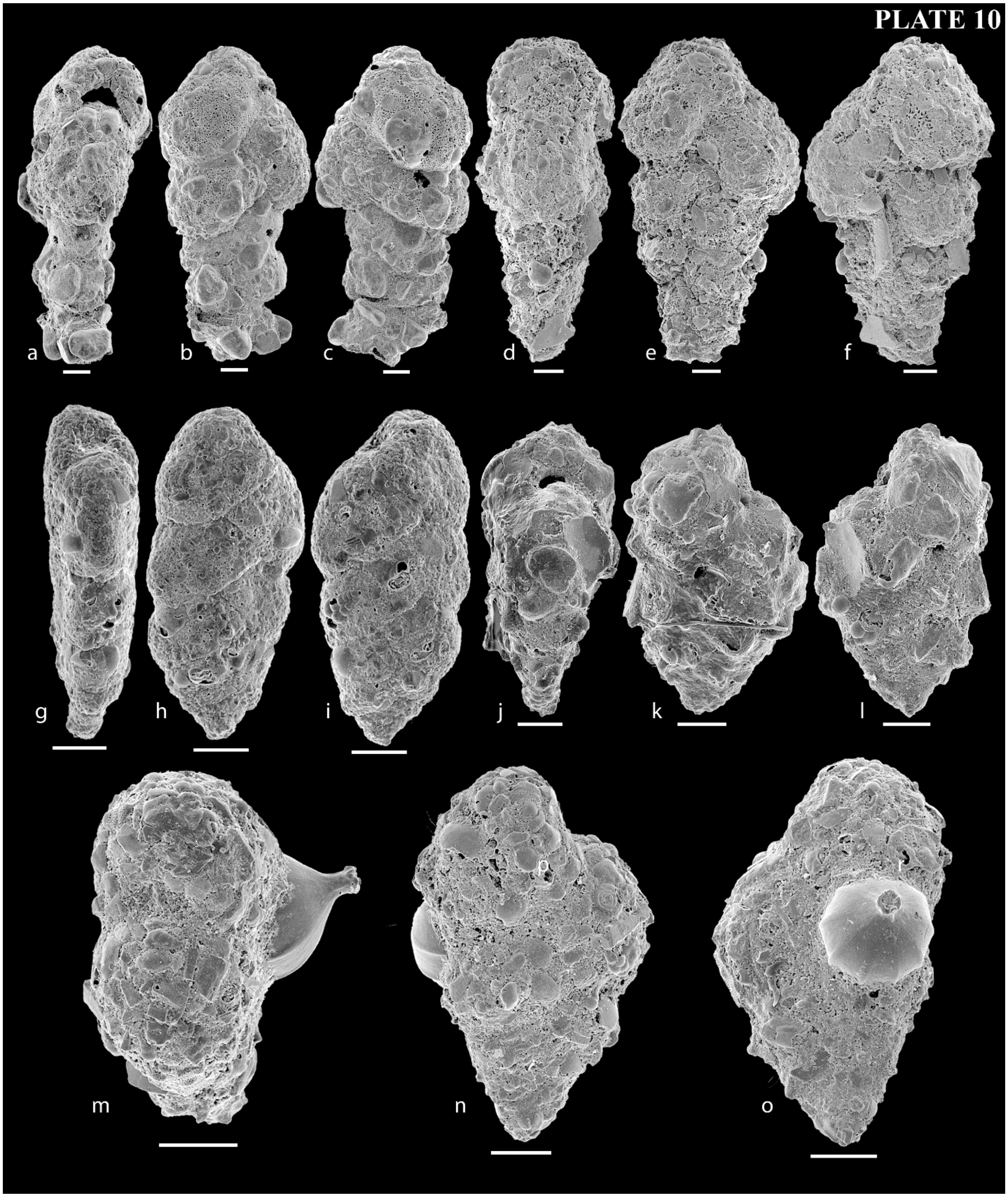
PLATE 10
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PLATE 11 (*Ammonia tepida – Ammonia convexa*)

a–c ***Ammonia tepida*** (a) apertural view (b) umbilical view (c) spiral view.

d–e ***Ammonia* cf. *A. tepida*** (d) spiral view (e) umbilical view.

f–g ***Ammonia* cf. *A. tepida*** (f) umbilical view (g) spiral view.

h–j ***Ammonia* sp. 1** (h) umbilical view (i) lateral view (j) apertural view.

k–m ***Ammonia convexa*** (k) umbilical view (l) lateral view (m) apertural view.

n–o ***Ammonia* cf. *A. aberdoveyensis*** (n) umbilical view (o) spiral view.

p–r ***Ammonia convexa*** (p) apertural view (q) umbilical view (r) spiral view.

s–t ***Ammonia convexa*** (s) umbilical view (t) spiral view.

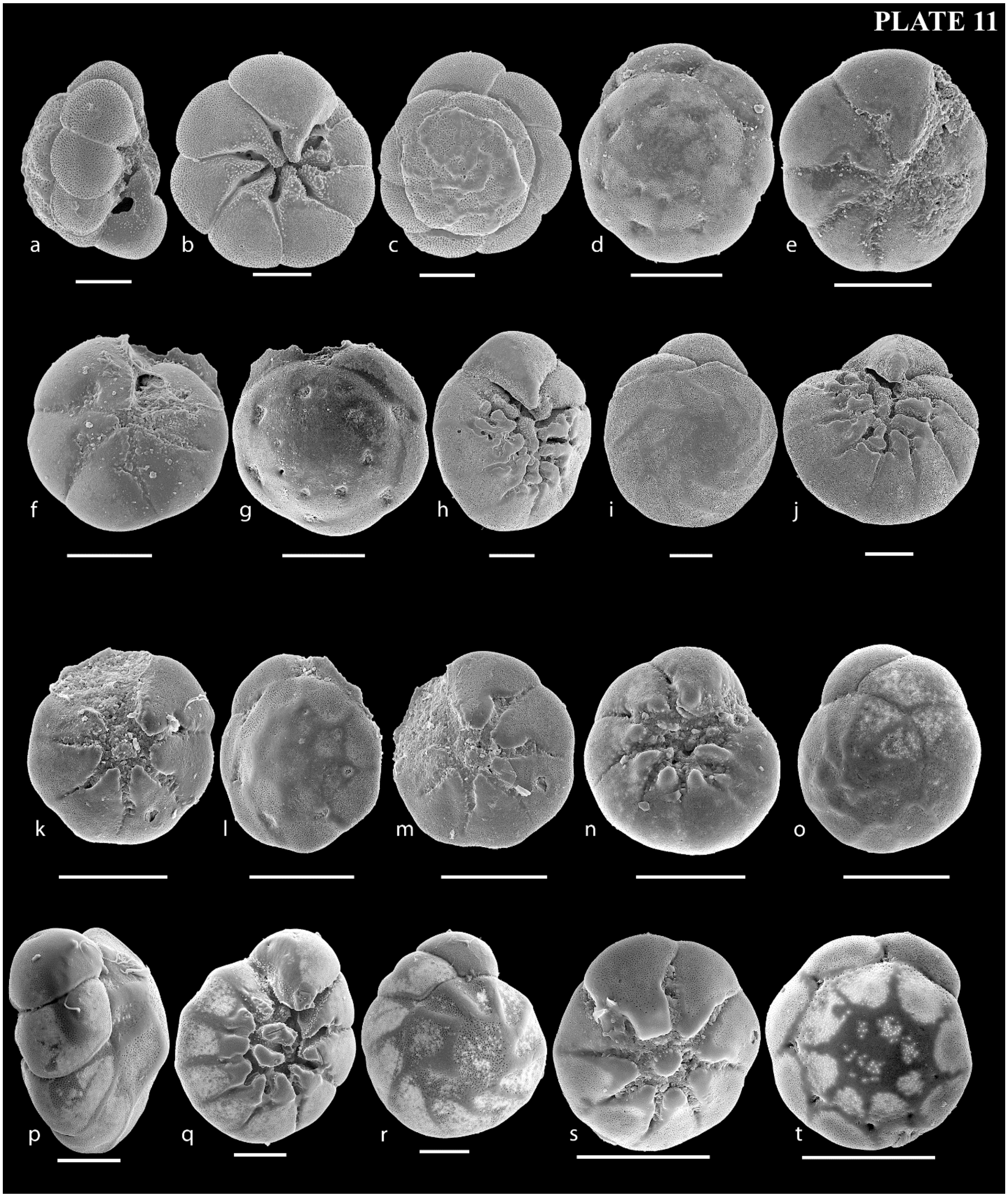
PLATE 11
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PLATE 12 (*Ammonia faceta* – *Ammonia* sp. 3)

a–c ***Ammonia faceta*** (a) apertural view (b) spiral view (c) umbilical view.

d–e ***Ammonia*** **cf.** ***A. aberdoveyensis*** (d) umbilical view (e) spiral view.

f–h ***Ammonia*** **cf** ***A. convexa*** (f) apertural view (g) umbilical view (h) spiral view.

i–k ***(?) Ammonia*** **sp.** (i) apertural view (j) spiral view (k) umbilical view.

l–n ***(?) Ammonia*** **sp.** (l) apertural view (m) spiral view (n) umbilical view.

o–p ***(?) Ammonia*** **sp.** ***(***o) spiral view (p) umbilical view.

q–s ***Ammonia*** **sp.** (q) side view (r) umbilical view (s) spiral view.

t–v ***Ammonia*** **sp. 3** (t) apertural view (u) umbilical view (v) spiral view.

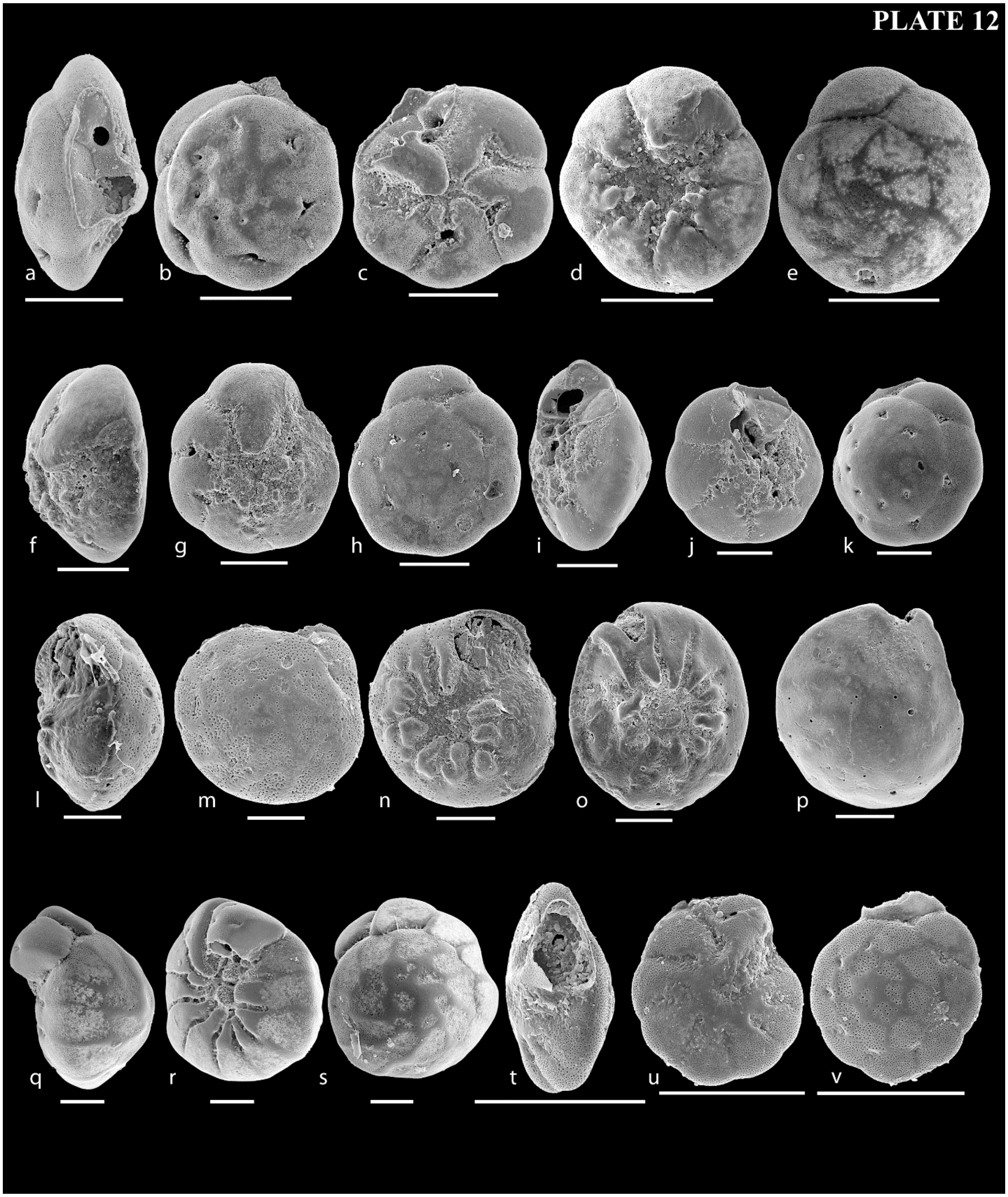
PLATE 12
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PLATE 13 (*Elphidium fichtellianum – Elphidium gerthi)*

a–d ***Elphidium fichtellianum*** (a) apertural view (b) lateral view (c) lateral view of the opposite side. (d) Enlarge view of the surface ornamentations.

e–h ***Elphidium fichtellianum*** (e) apertural view (g) lateral view (h) lateral view of the opposite side.

i–k ***Elphidium fichtellianum*** (i) apertural view (j) lateral view (k) lateral view of the opposite side.

l–n ***Elphidium gerthi*** (l) apertural view (m) lateral view (n) lateral view of the opposite side.

o–q ***Elphidium maorium*** (o) apertural view (p) lateral view (q) lateral view of the opposite side.

r–t ***Elphidium gerthi*** (r) apertural view (s) lateral view (t) lateral view of the opposite side.

u–v ***Elphidium gerthi*** (u) apertural view (v) lateral view.


PLATE 13
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PLATE 14 (*Elphidium craticulatum – Elphidium advenum)*

a–c ***Elphidium craticulatum*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Elphidium tongaense*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Elphidium macelliforme*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Elphidium advenum*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Elphidium advenum*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Elphidium advenum*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Elphidium advenum*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–w ***Elphidium advenum*** (v) apertural view (w) lateral view.

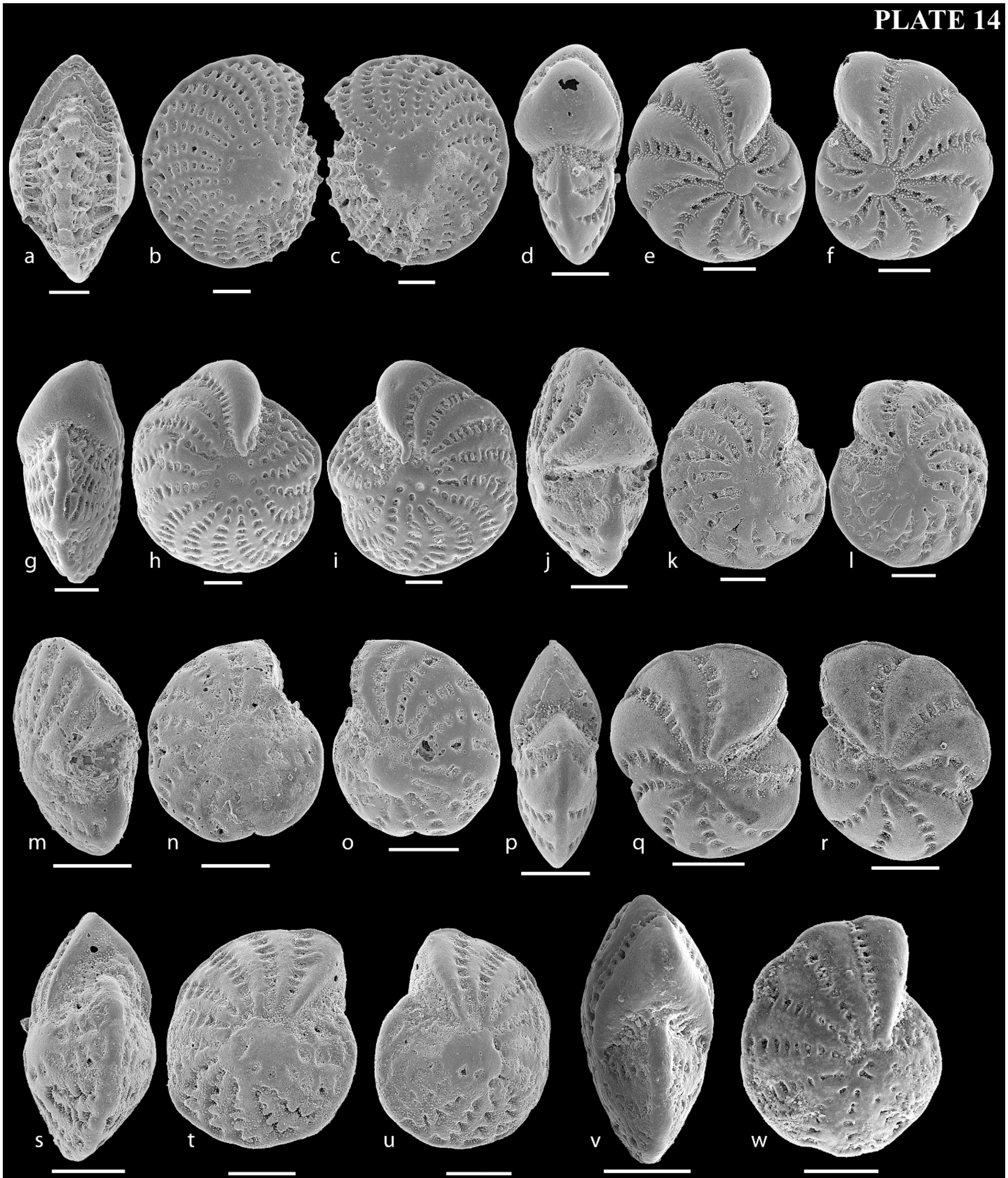
PLATE 14
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PLATE 15 (*Elphidium neosimplex – Elphidium neosimplex*)

a–c ***Elphidium neosimplex*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Elphidium neosimplex*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Elphidium neosimplex*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Elphidium neosimplex*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Elphidium neosimplex*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Elphidium neosimplex*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Elphidium neosimplex*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Elphidium neosimplex*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

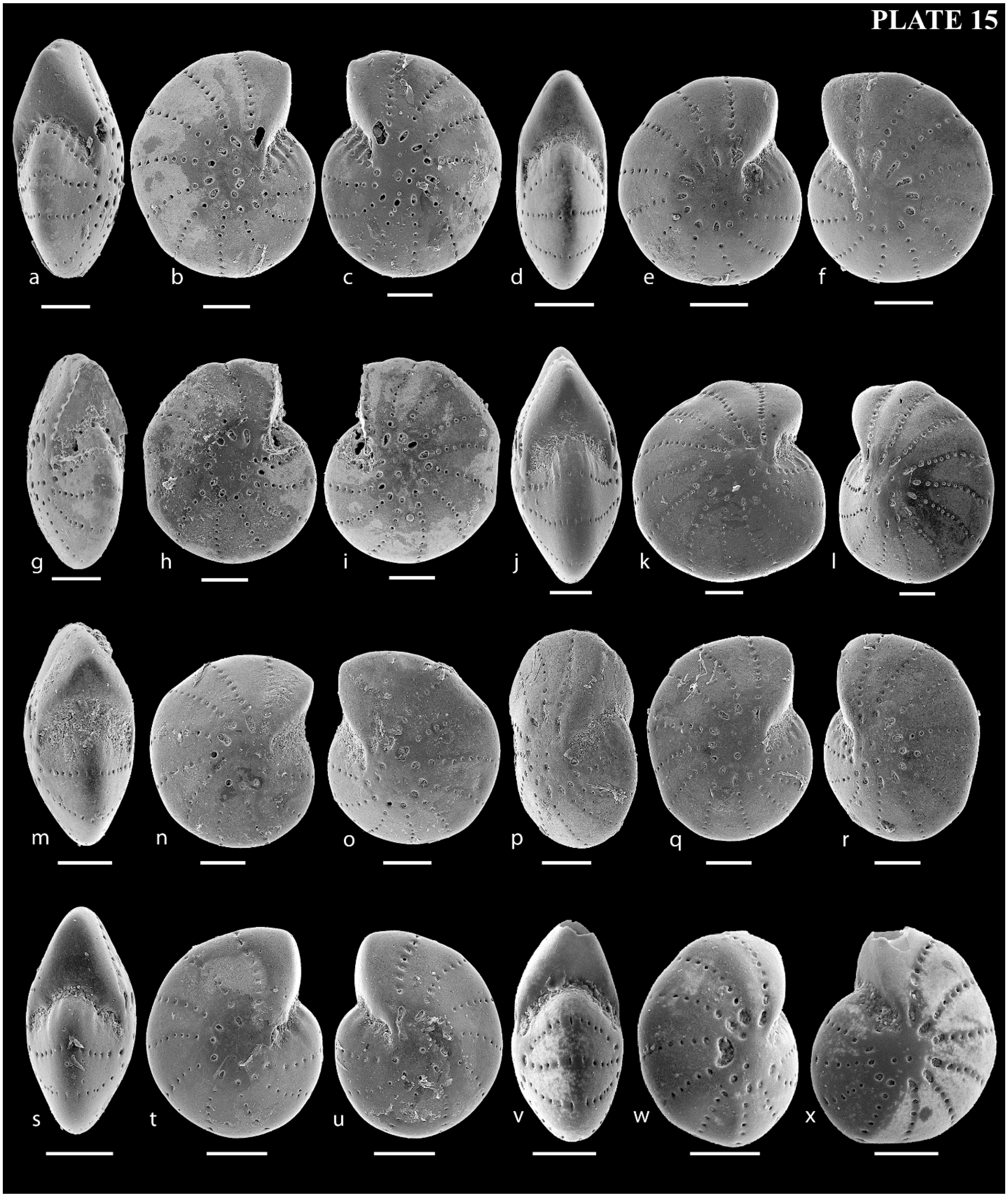
PLATE 15
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PLATE 16 (*Elphidium* cf. *E. hawkesburiensis* – *Parrellina hispidula)*

a–c ***Elphidium* cf. *E. hawkesburiensis*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Parrellina hispidula*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Parrellina hispidula*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Parrellina hispidula*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Parrellina hispidula*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Parrellina hispidula*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.


PLATE 16
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PLATE 17 (*Glabratella* sp. 1–*Rosalina* sp.)

a–b ***Glabratella* sp. 1** (a) umblical view (b) spiral view

c–e ***Glabratellina* sp. 1** (c) umblical view (d) spiral view (e) side view.

f–g ***Gavelinopsis sp*** (f) umblical view (g) spiral view

h–j ***Rosalina bradyi*** (h) lateral view (i) umblical view (j) spiral view.

k–l ***Rosalina bradyi*** (k) umblical view (l) spiral view.

m–o ***Rosalina bradyi*** (m) side view (n) umblical view (o) spiral view.

p–q ***Rosalina bradyi*** (p) spiral view (q) umblical view

r–t ***Rosalina* sp.** (r) side view (s) spiral view (t) umbilical view.

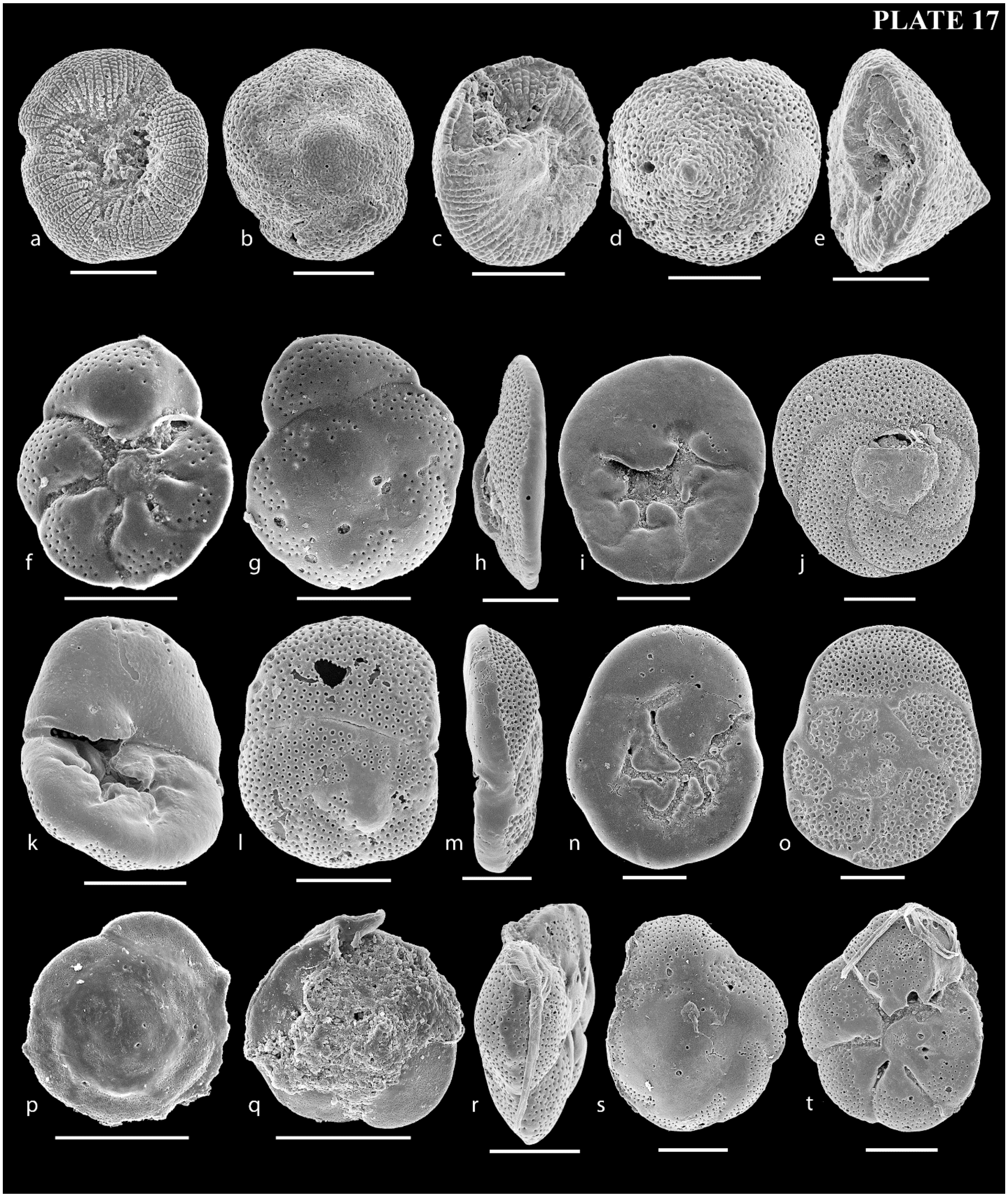
PLATE 17
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PLATE 18 (*Cymbaloporetta bradyi* b – *(?) Rosalina* sp.)

a–c ***Cymbaloporetta bradyi*** (a) side view (b) umbilical view (c) spiral view.

d ***Cymbaloporetta* cf. *C. bradyi*** (d) spiral view, attached as an epibiont.

e–g ***Cymbaloporetta* cf. *C. bradyi (***e) side view (g) umbilical view.

h–i ***Cymbaloporetta* sp.** (h) lateral view (i) spiral view (j) umbilical view.

k–m ***Acervulina mahabeti*** (m) side view (n) lateral view (o) lateral view of the opposite side.

n–p ***Acervulina mahabeti (***n) side view (o) lateral view (p) lateral view of the opposite side.

q–s ***Planorbulina* sp.** (q) side view (r) lateral view (s) lateral view of the opposite side.

t–v ***(?) Rosalina* sp.** (t) side view (r) lateral view (s) lateral view of the opposite side.

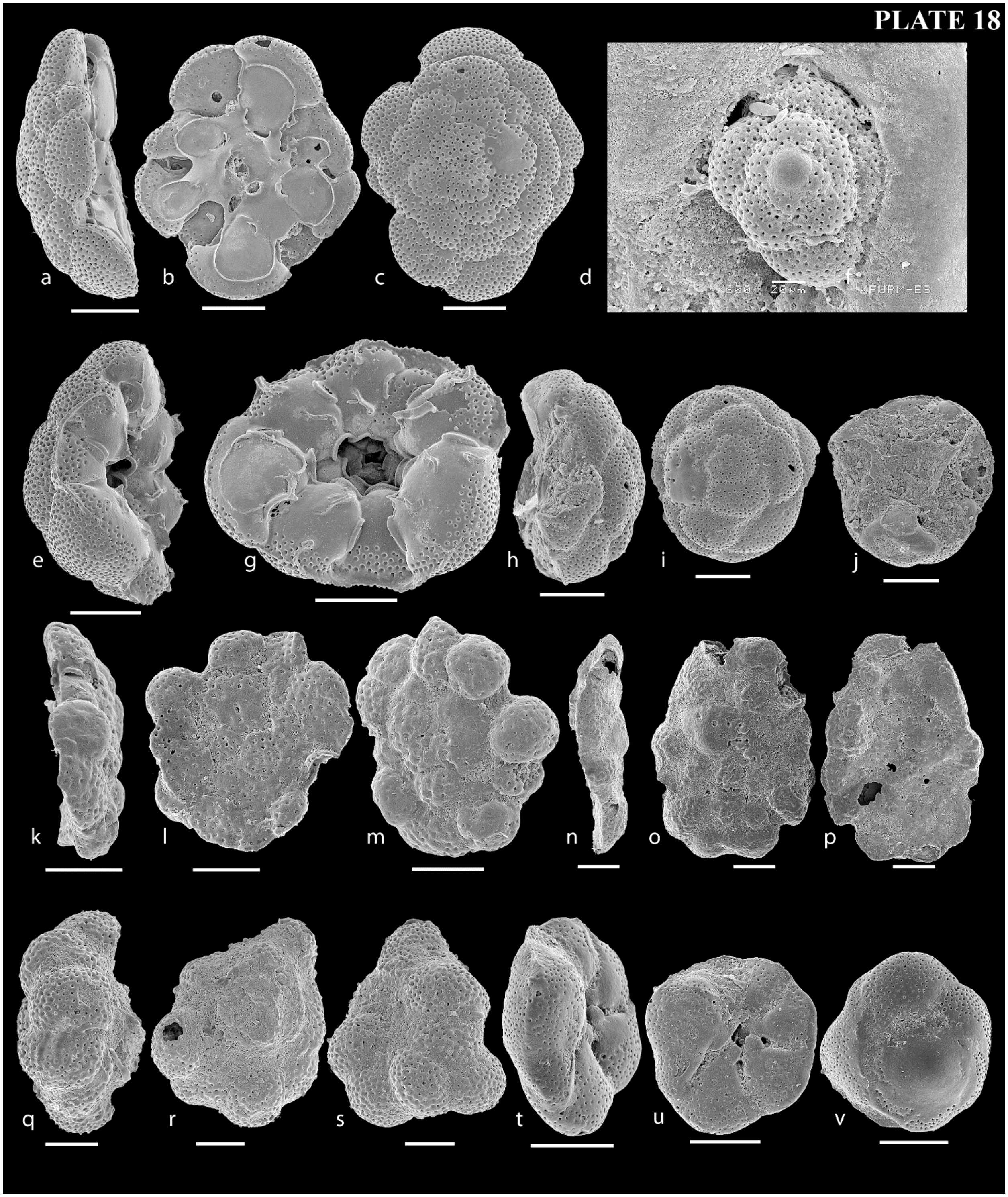
PLATE 18
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PLATE 19 (*Rosalina* sp. 05–*Epondes* sp.)

a–c ***Rosalina* sp. 05** (a) side view (b) umbilical view (c) spiral view.

d–f (?) ***Rosalina* sp. 02** (d) apertural view (e) umbilical view (f) spiral view.

g–i (?) ***Rosalina* sp. 04** (g) apertural view (h) spiral view.

i–k ***Porosononion* sp. 1** (i) apertural view (j) lateral view (k) lateral view of the opposite side.

l–n ***Porosononion* sp. 2** (l) apertural view (m) lateral view (n) lateral view of the opposite side.

o–q ***Porosononion* sp. 3** (o) apertural view (p) lateral view (q) lateral view of the opposite side.

s–u ***Porosononion* sp. 4** (r) apertural view (s) lateral view (t) lateral view of the opposite side.

v–x (?) ***Epondes* sp.** (u) apertural view (v) lateral view.


PLATE 19
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PLATE 20 (*Asterorotalia* sp. 2 – *Asterorotalia* sp. 7)

a–c ***Asterorotalia* dentata** (a) side view (b) umbilical view (c) spiral view.

d–e ***Asterorotalia* dentata** (d) apertural view (e) spiral view.

f–h ***Asterorotalia* inflata** (f) side view (g) umbilical view (h) spiral view.

i–j ***Asterorotalia* sp. 4** (i) umbilical view (j) spiral view.

k–m ***Asterorotalia* sp. 3** (k) apertural view (l) umbilical view (m) spiral view.

n–o ***Asterorotalia* sp. 1** (n) umbilical view (o) spiral view.

p–r ***Asterorotalia* sp. 6** (p) apertural view (q) spiral view (r) umbilical view.

s–u ***Asterorotalia* sp. 7** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

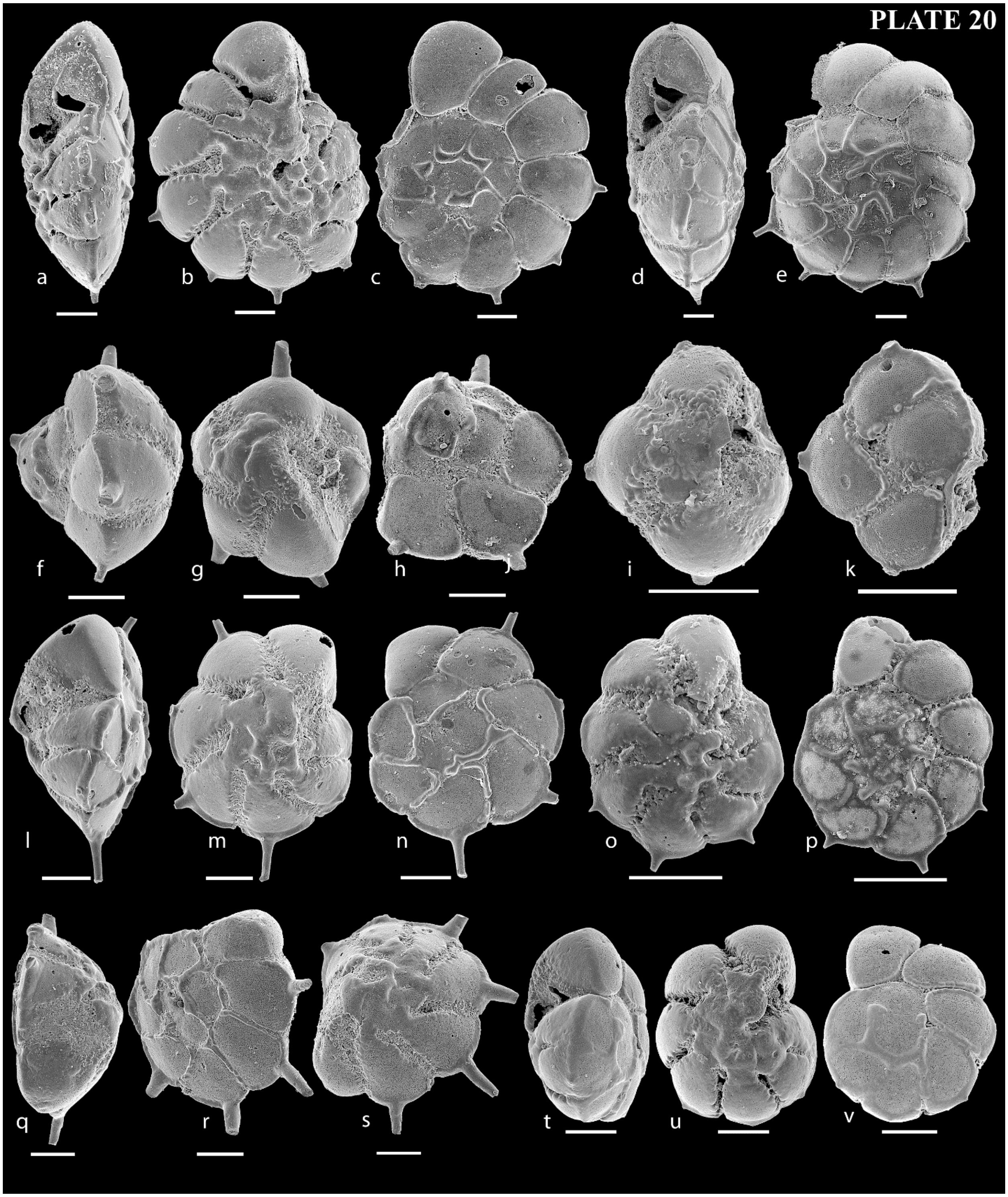
PLATE 20
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PLATE 21 (*Asterorotalia* sp. 6 – *Challengerella persica)*

a–c ***Asterorotalia* sp. 8** (a) apertural view (b) umbilical view (c) spiral view.

d–f ***Asterorotalia* sp. 9** (d) apertural view (e) umbilical view (f) spiral view.

g–i ***Asterorotalia* sp. 10** (g) apertural view (h) umbilical view (i) spiral view.

j–l ***Asterorotalia gaimardi*** (j) apertural view (k) umbilical view (l) spiral view.

m–o ***Challengerella* sp. 2** (m) apertural view (n) umbilical view (o) spiral view.

p–q ***Asterorotalia* cf *A. gaimardi*** (p) spiral view (q) spiral view

r–t ***Challengerella* cf. *C. persica*** (r) apertural view (s) umbilical view (t) spiral view.

u–v ***Challengerella persica*** (v) side view (w) spiral view.

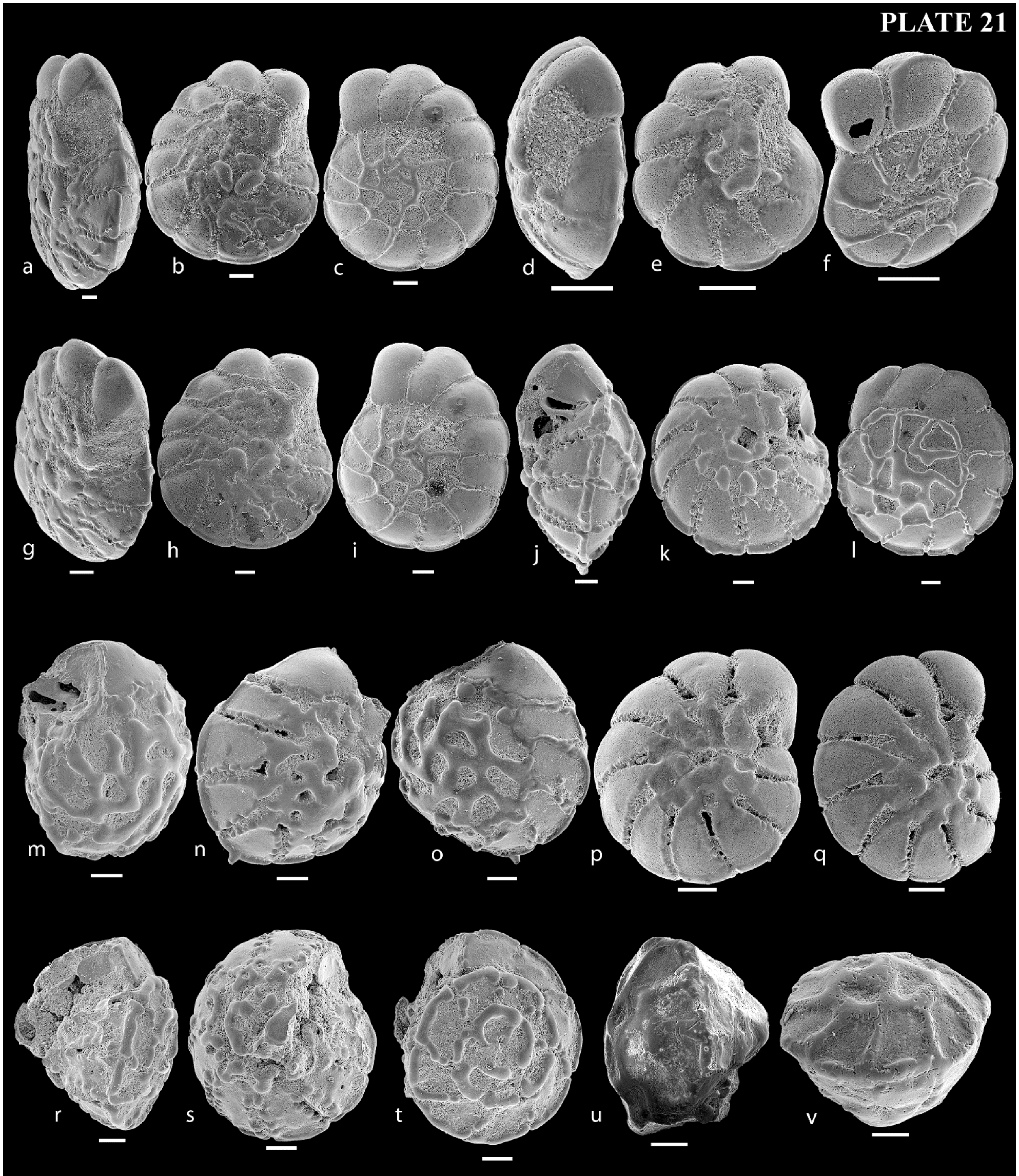
PLATE 21
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PLATE 22 (*Challengerella* sp. 01 – *Pyramidulina* sp. 01)

a–c ***Uvigerina* cf. *U. peregrina*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Pyramidulina* sp. 1** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Challengerella* sp. 1** (g) apertural view (h) unbilical view (i) spiral view.

j–l ***Uvigerina* cf. *U. proboscidea*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

m–o ***Amphisterigina lessonii*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Assilina* sp.** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Challengerella* sp. 3** (s) apertural view (t) umbilical view (u) spiral.


PLATE 22
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PLATE 23 ((?) ***Oolina*** **sp. 1 –** ***Fissurina*** **sp. 01)**

a–c (?) ***Oolina*** **sp. 1** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f (?) ***Oolina*** **sp. 2** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Glandulina laevigata*** (g) apertural view (h) lateral view (i) posterior view.

j–l ***Glandulina*** **cf.** ***G. laevigata*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Glandulina*** **sp. 2** (m) apertural view (n) lateral view (o) posterior view

p–r ***Fissurina*** **cf.** ***F. bispinata*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Fissurina lucida (***s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–w ***Fissurina*** **sp. 1** (v) apertural view (w) lateral view.

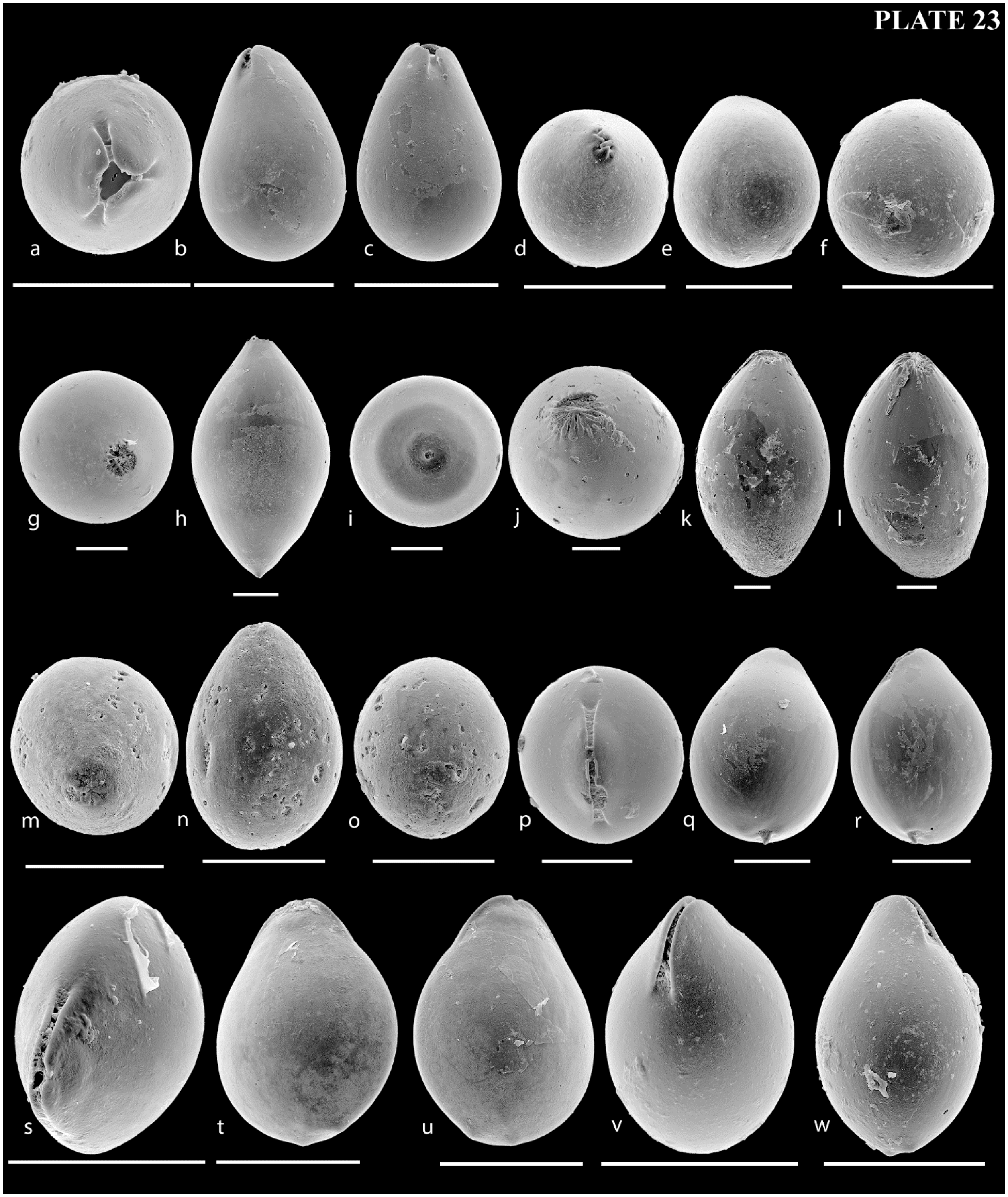
PLATE 23
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PLATE 24 (*Lagena* cf. *L. strumosa* – *Lagena* sp. 03)

a–c ***Lagena* cf. *L. strumosa*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Lagena* cf. *L. semistriata*** (d) apertural view (e) lateral view (f) posterior view.

g–i ***Lagena* cf. *L. strumosa*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Lagena semistriata*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Lagena strumosa*** (m) apertural view (n) lateral view (o) posterior view.

p–r ***Lagena* sp. 01** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Lagena* sp. 02** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Lagena* sp. 03** (v) apertural view (w) posterior view (x) lateral view.

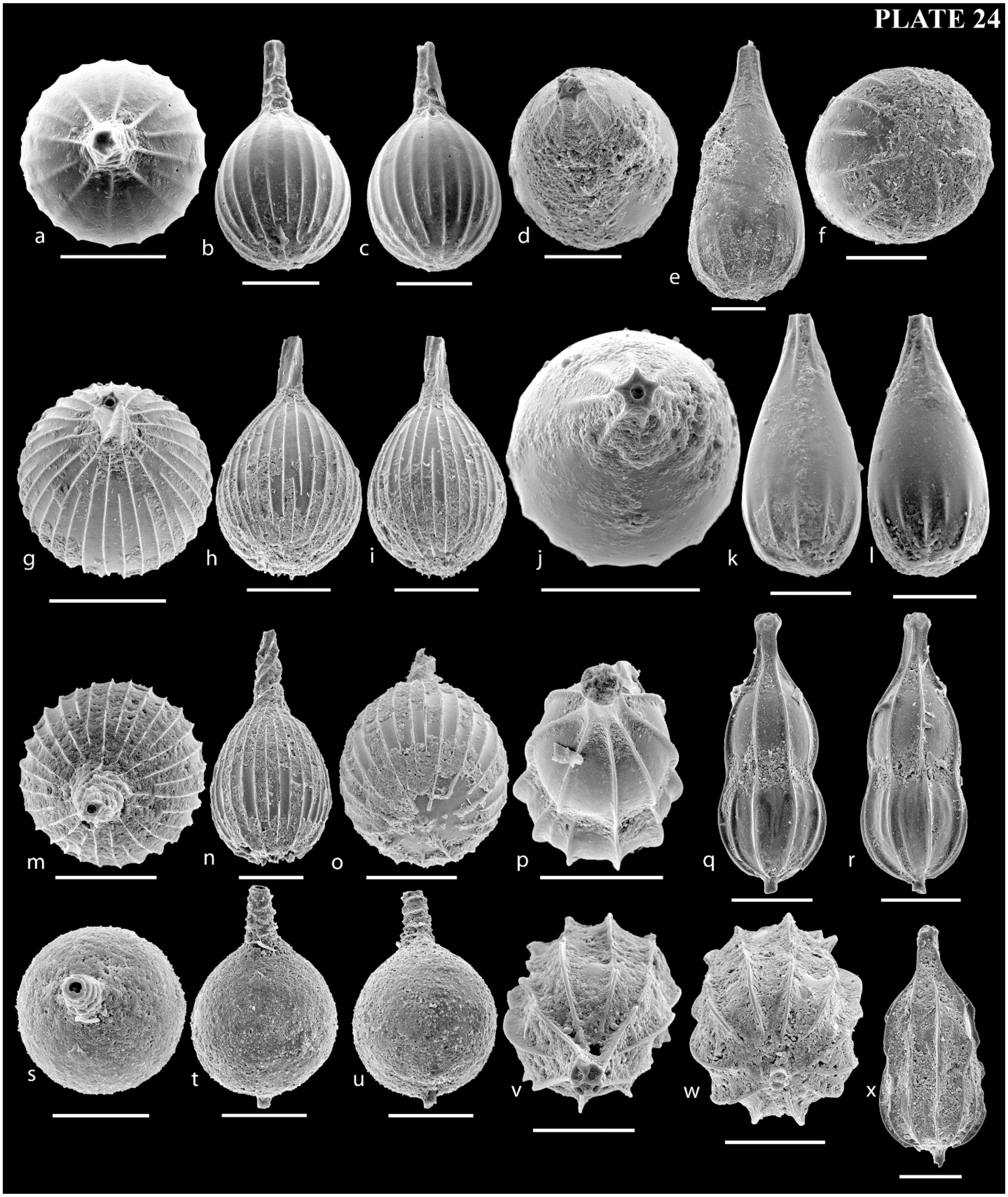
PLATE 24
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PLATE 25 ((?) *Praebulimina* sp. – *Cancaris* cf. *C. bubnanensis*)

a–c **(?) *Praebulimina* sp.** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Cancaris* cf. *C. bubnanensis*** (d) apertural view (e) umbilical view (f) spiral view of the opposite side.

g–i ***Cancaris bubnanensis*** (g) anterior view (h) side view (i) umbilical view.

j–l ***Cancaris* cf. *C. bubnanensis*** (j) apertural view (k) umbilical view (l) spiral view.

m–o ***Cancaris* cf. *C. bubnanensis*** (m) posterior view (n) spiral view (o) umbilical view.

p–r ***Cancaris* cf. *C. bubnanensis*** (p) side view (q) spiral view (r) umbilical view.

s–u ***Cancris* cf. *C. oblongus*** (s) apertural view (t) spiral view (u) umbilical view.

v–x ***Cancaris* cf. *C. oblongus*** (v) apertural view (w) spiral view (x) umbilical view.

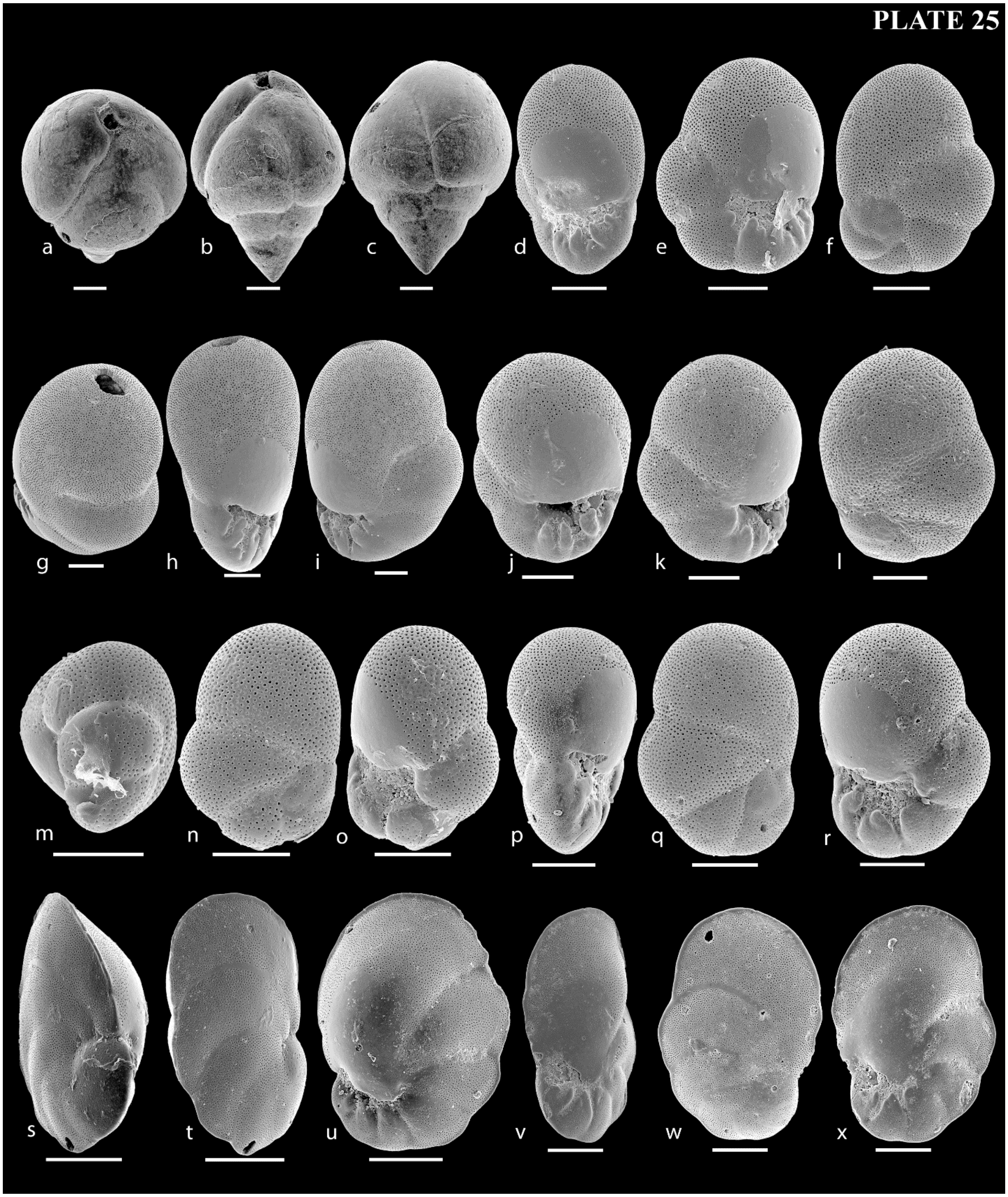
PLATE 25
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PLATE 26 (*Cancaris* cf. *C. auricularis* – *Hanzawaia* sp. 3)

a–c ***Cancaris* cf. *C. auricularis*** (a) apertural view (b) umbilical view (c) spiral view.

d–f ***Cancaris* cf. *C. auricularis*** (d) apertural view (e) spiral view (f) umbilical view.

g–i ***Cancaris* cf. *C. auricularis*** (g) apertural view (h) spiral view (i) umbilical view.

j–l ***Cancaris* cf. *C. auricularis*** (j) lateral view (k) spiral view (l) umbilical view.

m–o ***Hanzawaia* sp.** (m) apertural view (n) spiral view (o) umbilical view.

p–r ***Lobatula lobatula*** (p) apertural view (q) spiral view (r) umbilical view.

s–u ***Hanzawaia* sp. 2** (s) apertural view (t) spiral view (u) umbilical view.

v–x ***Hanzawaia* sp. 3** (v) apertural view (w) spiral view (x) umbilical view.

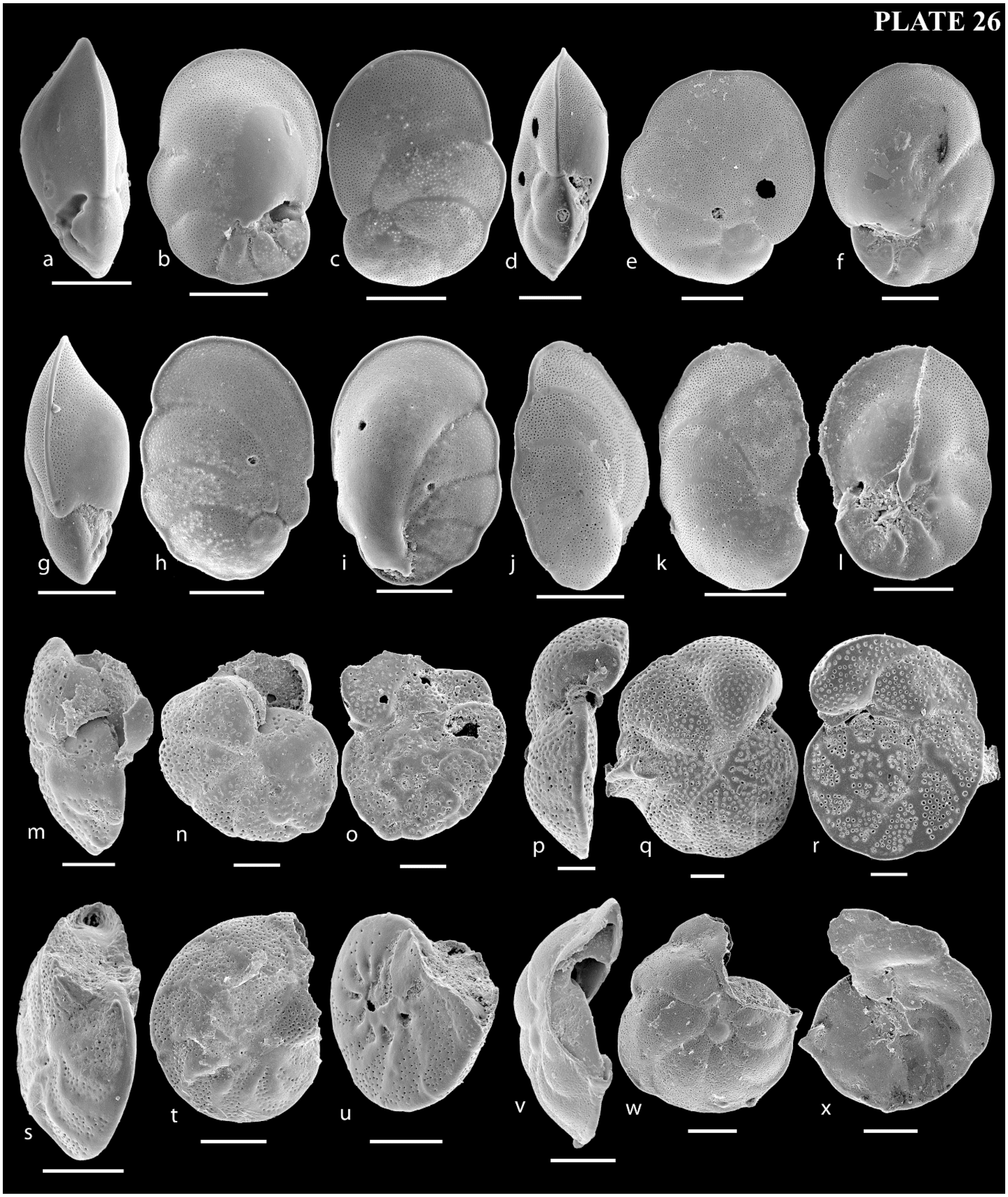
PLATE 26
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PLATE 27 (*Hanzawaia* sp 4 – *Cibicides* cf. *C. philippinensis*)

a–c ***Hanzawaia* sp. 4** (a) apertural view (b) umbilical view (c) spiral view.

d–f ***Hanzawaia* sp. 5** (d) apertural view (e) spiral view (f) umbilical view.

g–i ***Hanzawaia* sp. 6** (g) apertural view (h) spiral view (i) umbilical view.

j–l ***Hanzawaia* sp. 7** (j) apertural view (k) umbilical view (l) spiral view.

m–o ***Cibicidoides* sp.** (m) apertural view (n) umbilical view (o) spiral view.

p–r ***Hanzawaia* sp.** (p) apertural view (q) spiral view (r) umbilical view.

s–u ***Cibicides* cf. *C. refugens*** (s) apertural view (t) spiral view (u) umbilical view.

v–x ***Cibicides* cf. *C. philippinensis*** (v) apertural view (w) umbilical view (x) spiral view.

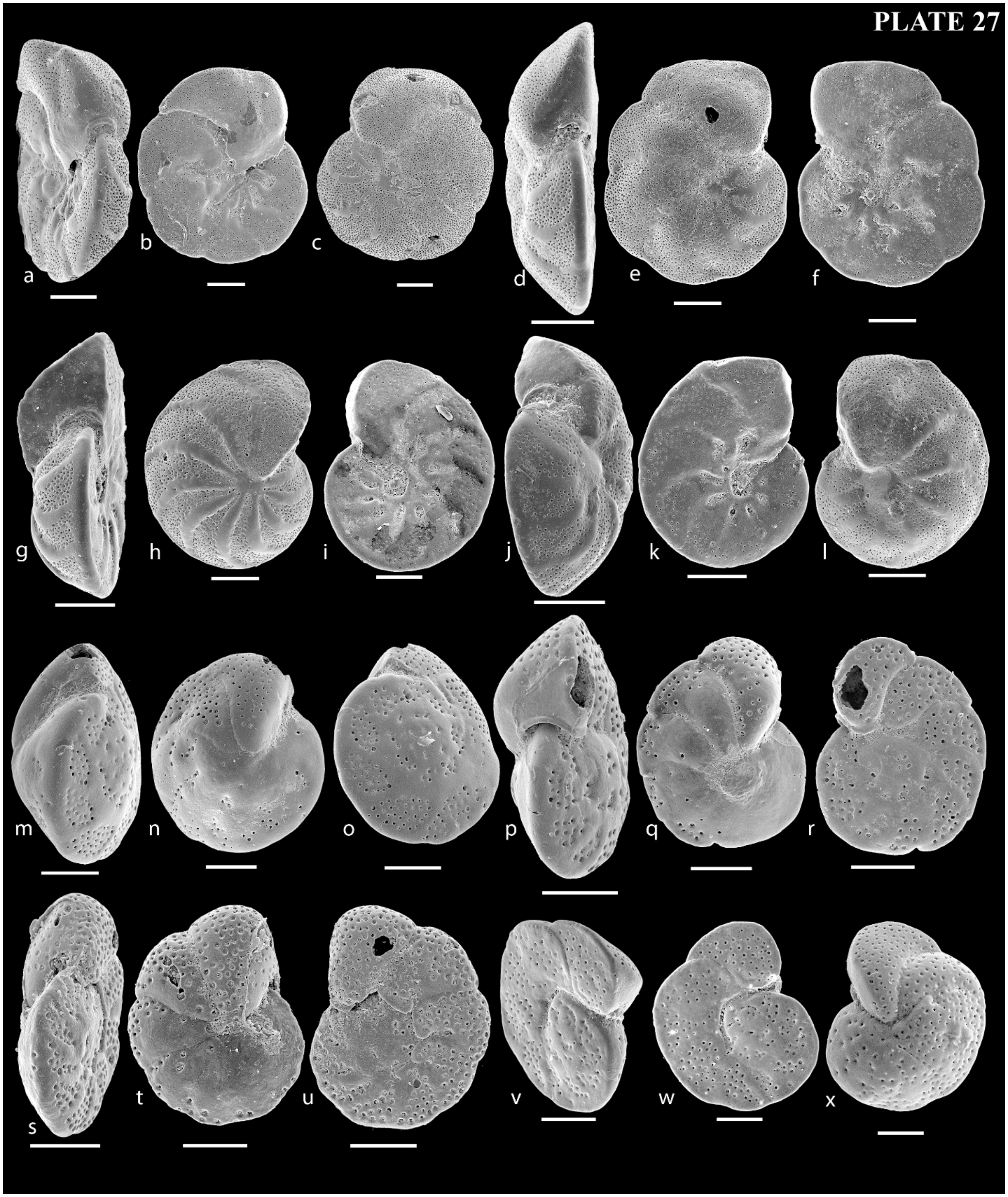
PLATE 27
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PLATE 28 (*Cibicides* cf. *C. refulgens* – *Cibicides* cf. *C. refulgens)*

a–c ***Cibicides* cf. *C. refulgens*** (a) apertural view (b) spiral view (c) umbilical view.

d–f ***Cibicides* cf. *C. refulgens*** (d) apertural view (e) spiral view (f) umbilical view.

g–i ***Cibicides* sp.** (g) apertural view (h) umbilical view (i) spiral view.

j–l ***Cibicidoides* sp. 1** (j) apertural view (k) umbilical view (l) spiral view.

m–n ***Cibicides* cf. *C. refulgens*** (m) umbilical view (n) spiral view.

o–q ***Cibicides* cf. *C. refulgens*** (o) apertural view (p) spiral view (q) umbilical view.


PLATE 28
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PLATE 29 (*Bulimina* cf. *B. biserialis* – *Bulimina* cf. *B. marginata)*

a–c ***Bulimina* cf. *B. biserialis*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Bulimina* cf. *B. biserialis*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Bulimina* sp. 1** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Bulimina* cf. *B. biserialis*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Bulimina* cf. *B. biserialis*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Bulimina* sp. 2** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Bulimina* sp. 4** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Bulimina* cf. *B. marginata*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

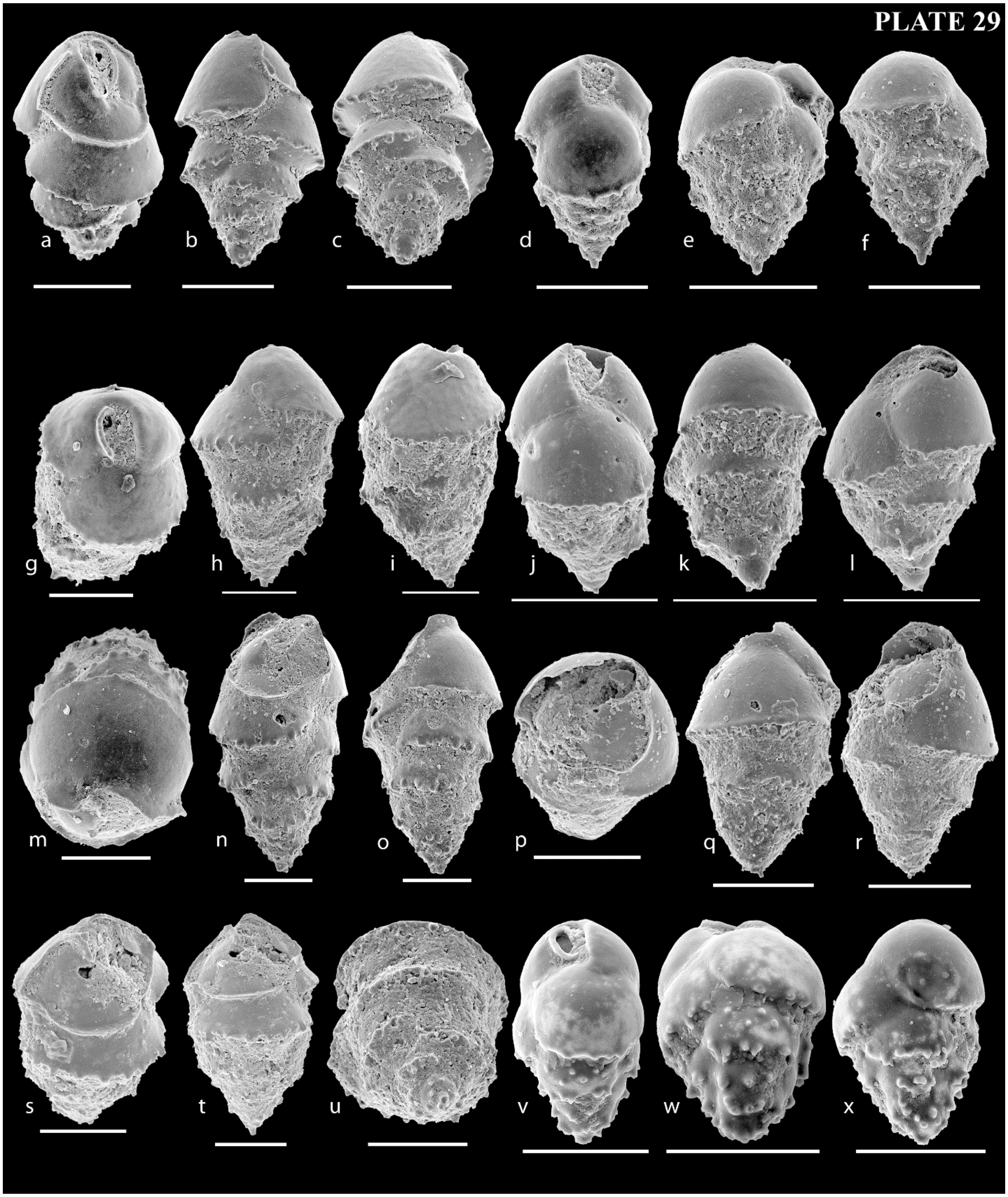
PLATE 29
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PLATE 30 (*Bulimina* cf. *B. marginata* – *Sigmavirgulina* sp. 03)

a–c ***Bulimina* cf. *B. marginata*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Bulimina* sp. 3** (d) apertural view (e) lateral view (f) posterior view.

g–i ***Fursenkoina* sp. 2** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Fursenkoina* sp. 4** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Fursenkoina* sp. 3** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Sagrinella lobata lobata*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Sagrinella lobata lobata*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–w ***Sigmavirgulina* sp. 2** (v) lateral view (w) side view.

x–z ***Sigmavirgulina* sp. 1** (x) side view (y) lateral view (z) lateral view of the opposite side.

aa–ac ***Sigmavirgulina* sp. 2** (aa) apertural view (ab) lateral view (ac) lateral view of the opposite side.

ad–af ***Sigmavirgulina* sp. 3** (ad) apertural view (ae) lateral view (af) lateral view of the opposite side.


PLATE 30
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PLATE 31 (*Loxostomina costulata – Brazilina striatula)*

a–c ***Loxostomina costulata*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Loxostomina* sp. 4** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Loxostomina* sp. 3** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Brizalina subspathulata*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Brazilina* cf. *B. subspathulata*** (m) apertural view (n) opposite side of apertural view (o) lateral view.

p–q ***Brazilina* cf. *B. subspathulata*** (p) apertural view (q) lateral view.

r–t ***Brazilina* cf. *B. subspathulata*** (r) apertural view (s) opposite view of apertural view (t) lateral view.

u–w ***Brizilina* cf. *B. striatula*** (u) apertural view (v) lateral view (w) lateral view of the opposite side.

x–y ***Brizalina striatula*** (x) lateral view (y) lateral view of the opposite side.

z–ab ***Brazilina striatula*** (z) apertural view (aa) lateral view (ab) lateral view of the opposite side.


PLATE 31
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PLATE 32 (*Brizalina striatula* – *Bolivina* cf. *B. persiensis*)

a–c ***Brizalina striatula*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Brizalina striatula*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–j ***Bolivina* cf. *B. suezensis*** (g) apertural view (h) lateral view (i) apertural view (j) lateral view of the opposite side.

k–m ***Bolivina* cf. *B. suezensis*** (k) apertural view (l) lateral view (m) lateral view of the opposite side.

n–o ***Bolivina* cf. *B. suezensis*** (n) lateral view (o) lateral view of the opposite side.

p–r ***Bolivina* cf. *B. suezensis*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Bolivina* cf. *B. plicata*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Bolivina* cf. *B. persiensis*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

y–aa ***Bolivina* cf. *B. persiensis*** (y) apertural view (z) lateral view (aa) lateral view of the opposite side.


PLATE 32
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PLATE 33 (*Bolivina* cf. *B. persiensis* – *Trimosina* cf. *T. milletti multispinata)*

a–c ***Bolivina* cf. *B. persiensis*** (a) apertural view (b) lateral view (c) apertural view (d) lateral view of the opposite side.

e–g ***Bolivina* cf. *B. persiensis*** (e) apertural view (f) lateral view (g) lateral view of the opposite side.

h–j ***Bolivinellina translucens*** (h) apertural view (i) lateral view (j) lateral view of the opposite side.

k–m ***Bolivinellina translucens*** (k) apertural view (l) lateral view (m) lateral view of the opposite side.

n–p ***Bolivinellina translucens*** (n) apertural view (o) lateral view (p) lateral view of the opposite side.

q–t ***Bolivinellina translucens*** (q) apertural view (r) lateral view (s) lateral view of the opposite side (t) lateral view of the opposite side.

u–w ***Bolivinellina* cf. *B. translucens*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

x–z ***Bolivinellina translucens*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

aa–ac ***Bolivina* cf. *B. persiensis*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

ad–af ***Bolivina* cf. *B. striatula*** (ad) apertural view (ae) lateral view (af) lateral view of the opposite side.

ag–ah ***Trimosina* cf. *T. milletti multispinata*** (ag) apertural view (ah) lateral view.

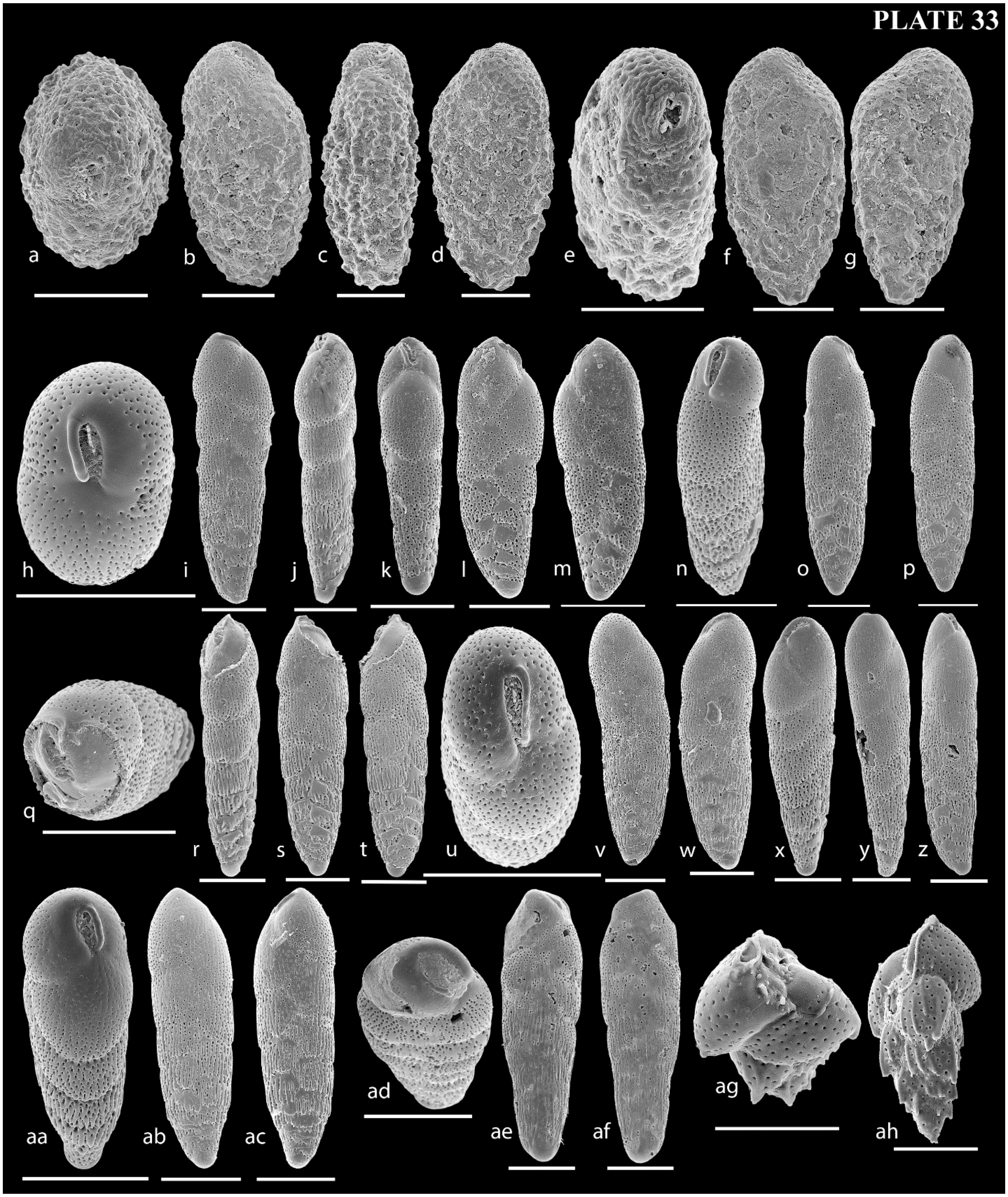
PLATE 33
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PLATE 34 (*Nonion* cf. *N. depressulus* – *Nonionella* cf. *N. iridea)*

a–c ***Nonion* cf. *N. depressulus*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Nonion* sp.** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Pseudononion japonicum*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Nonion* sp. 03** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Nonionella* cf. *N. labradorica*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Nonion* sp. 04** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Nonionella* cf. *N. labradorica*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–w ***Nonionella* cf. *N. iridea*** (v) lateral view (w) lateral view of the opposite side.


PLATE 34
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PLATE 35 (*Pseudonubeculina* sp. – *Agglutinella robusta*)

a–c ***Pseudonubeculina arabica*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Pseudonubeculina arabica*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Nubeculina* sp.** (g) apertural view (h) lateral view (i) posterior view.

j–l ***Pseudonubeculina arabica*** (j) anterior view (k) lateral view (l) posterior view.

m–o ***Agglutinella aggutinans*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Agglutinella aggutinans*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Agglutinella arenata*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Agglutinella arenata*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

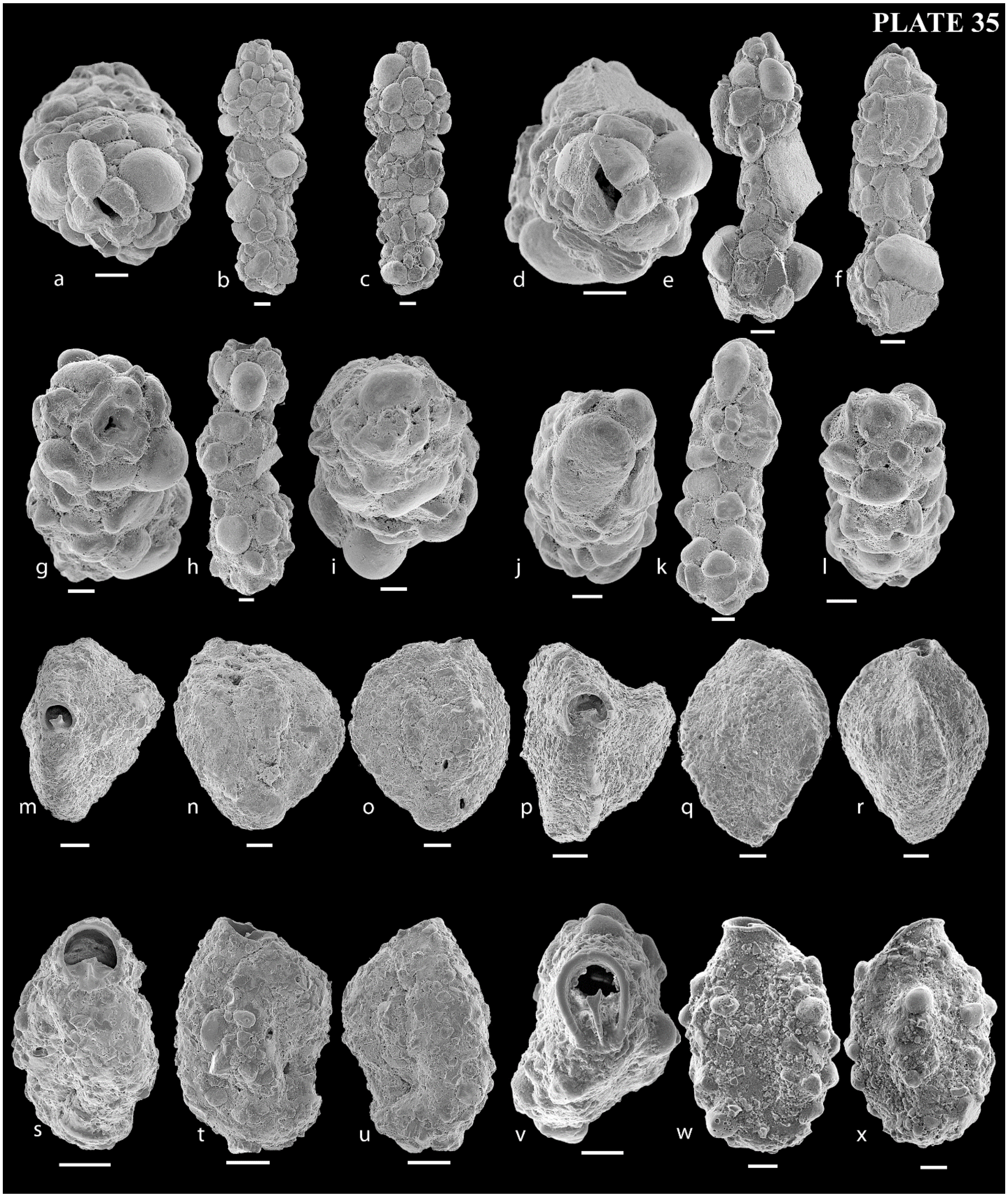
PLATE 35
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PLATE 36 (*Agglutinella compressa – Siphonaperta* sp. 10)

a–c ***Agglutinella compressa*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Agglutinella soriformis*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Siphonaperta pittensis*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Siphonaperta pittensis*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Siphonaperta* sp. 4** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Siphonaperta* sp. 8** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Siphonaperta* sp. 9** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Siphonaperta* sp. 10** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

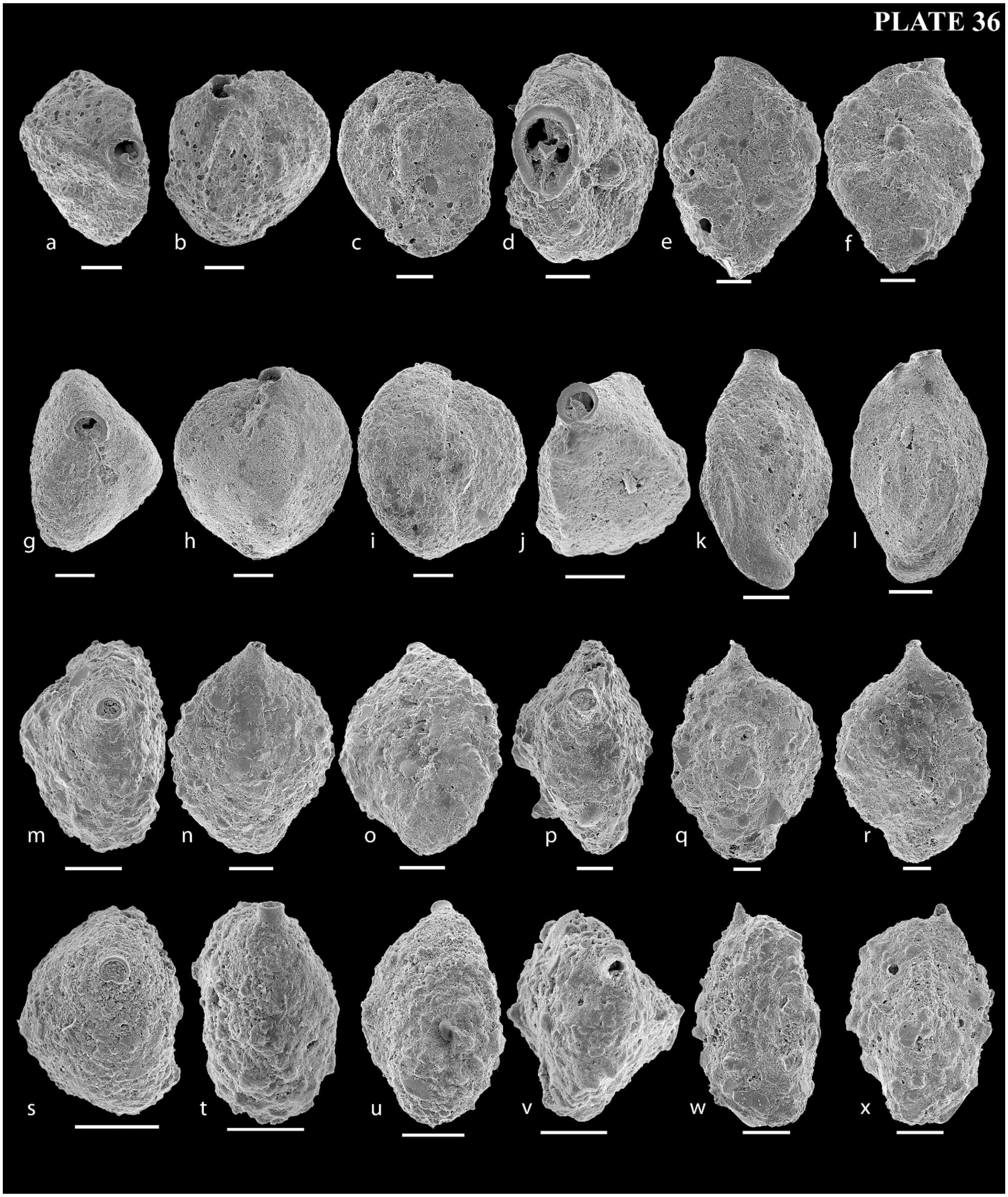
PLATE 36
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PLATE 37 (*Siphonaperta* sp. 11 – *Sigmoilopsis* cf. *S. herzensteini*)

a–c ***Siphonaperta* sp. 11** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Siphonaperta* sp. 12** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Siphonaperta agglutinans*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Sigmoilopsis* sp. 6** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Sigmoilopsis* sp. 1** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Sigmoilopsis* sp. 2** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Sigmoilopsis* cf. *S. herzensteini*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Sigmoilopsis* cf. *S. herzensteini*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

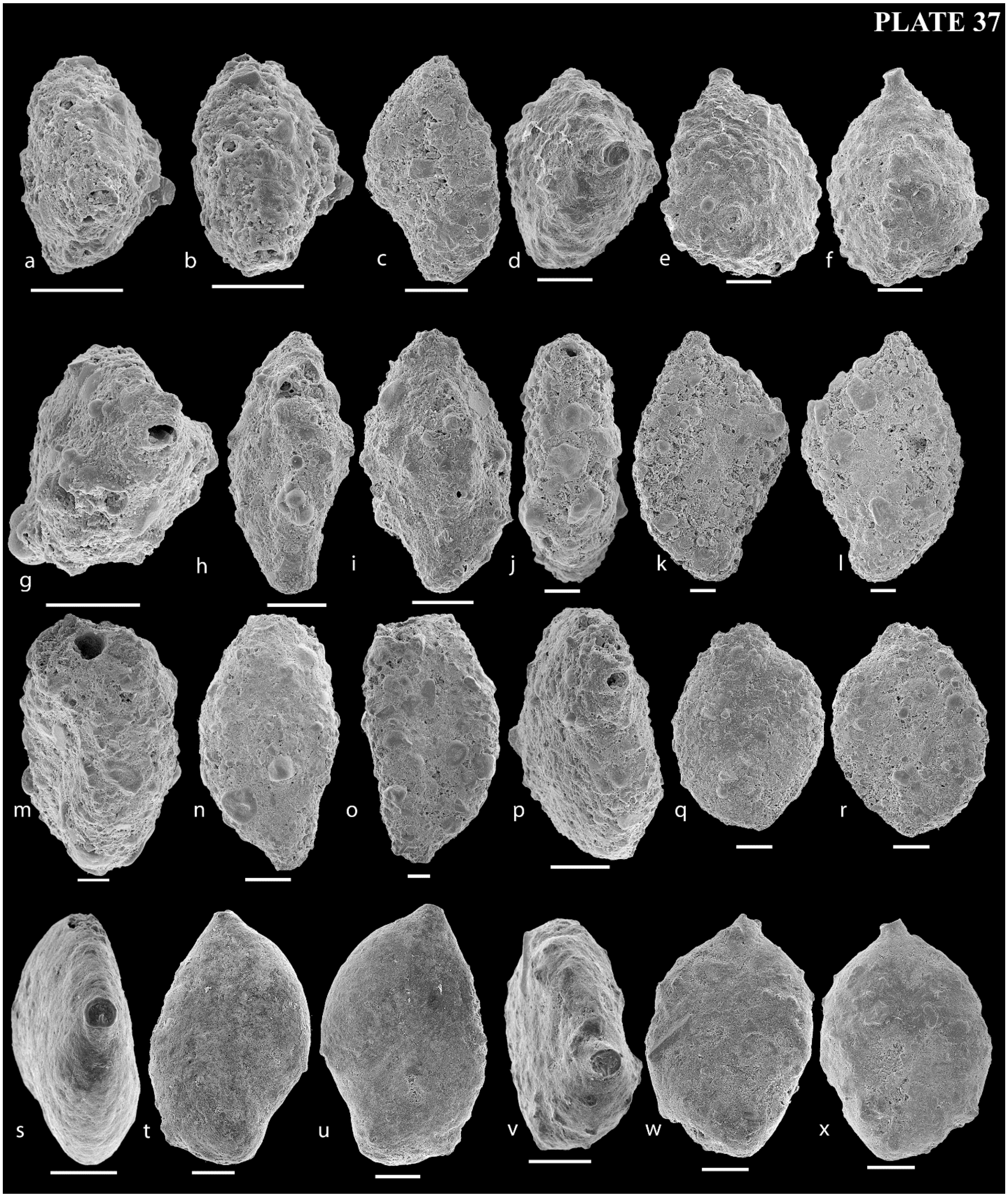
PLATE 37
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PLATE 38 (*Sigmoilopsis* sp. 07 – *Quinqueloculina arenata*)

a–c ***Sigmoilopsis* sp. 7** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Sigmoilopsis* sp. 3** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Sigmoilopsis* sp. 4** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Sigmoilopsis* sp. 5** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina arenata*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

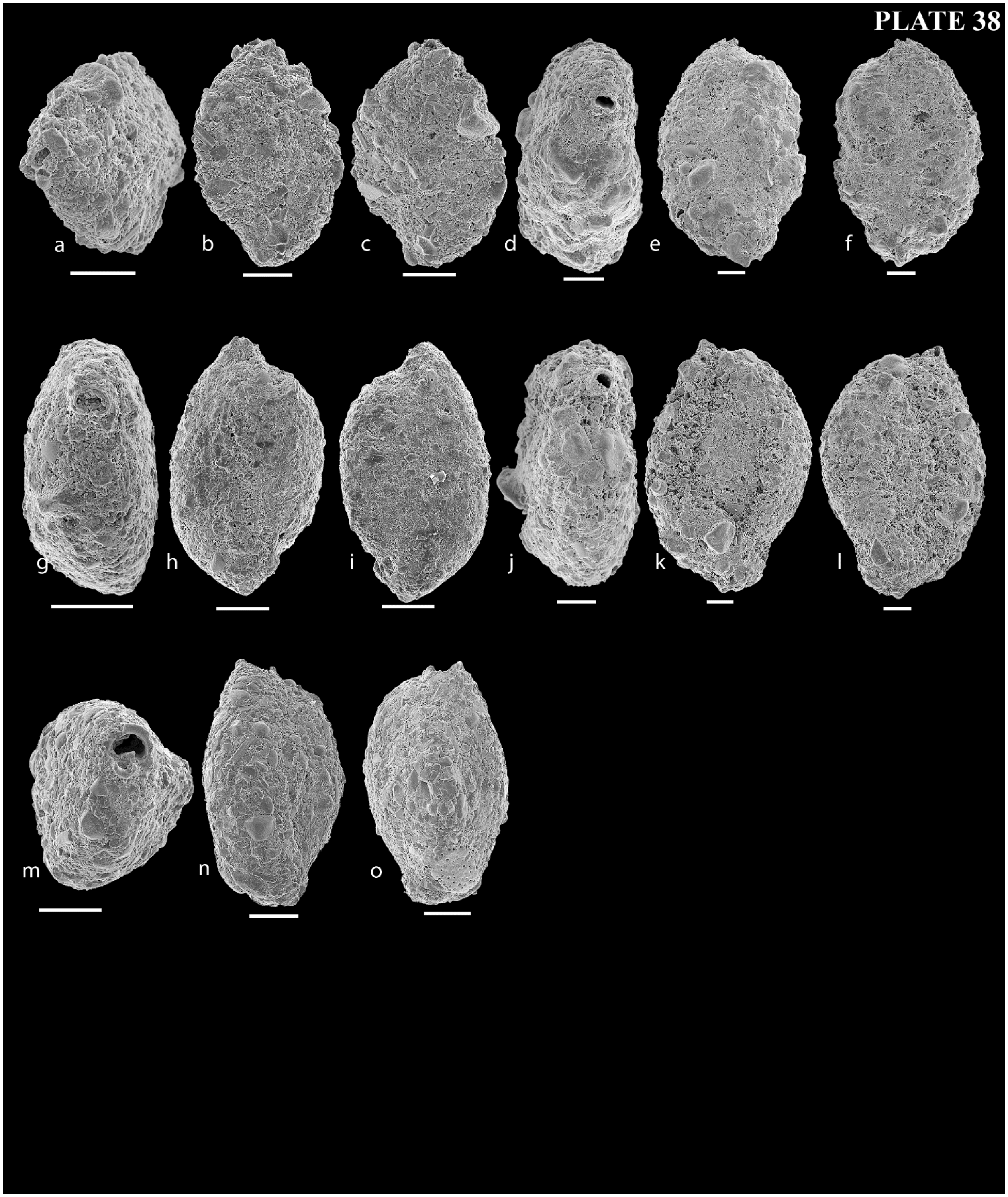
PLATE 38
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PLATE 39 (*Triloculina* cf. *T. serrulata* – *Triloculina* cf. *T. verspertilio*)

a–c ***Triloculina* cf. *T. serrulata*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Triloculina* cf. *T. serrulata*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Triloculina* cf. *T. serrulata*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Triloculina* cf. *T. serrulata*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Triloculina* cf. *T. serrulata*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Triloculina* cf. *T. vespertilio*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Triloculina* cf. *T. vespertilio*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Triloculina* cf. *T. verspertilio*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

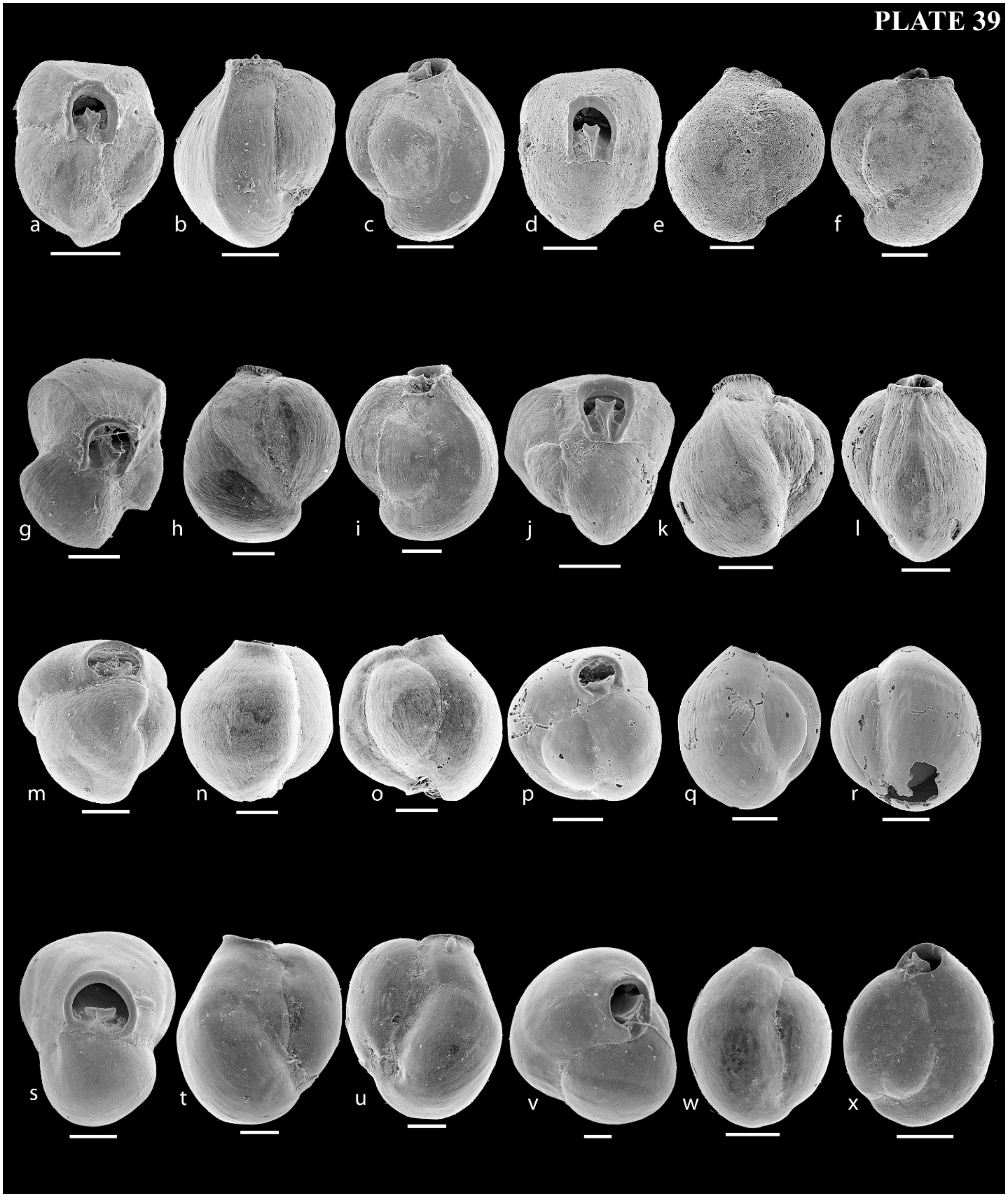
PLATE 39
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PLATE 40 (*Triloculina* cf. *T. fichteliana – Triloculina marioni*)

a–c ***Triloculina* cf. *T. fichteliana*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Triloculina* cf. *T. fichteliana*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Triloculina* cf. *T. fichteliana*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Triloculina* sp. 05** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Trilocula* sp. 04** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Triloculina* sp. 02** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Triloculina* sp. 01** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–w ***Triloculina marioni*** (v) apertural view (w) lateral view.

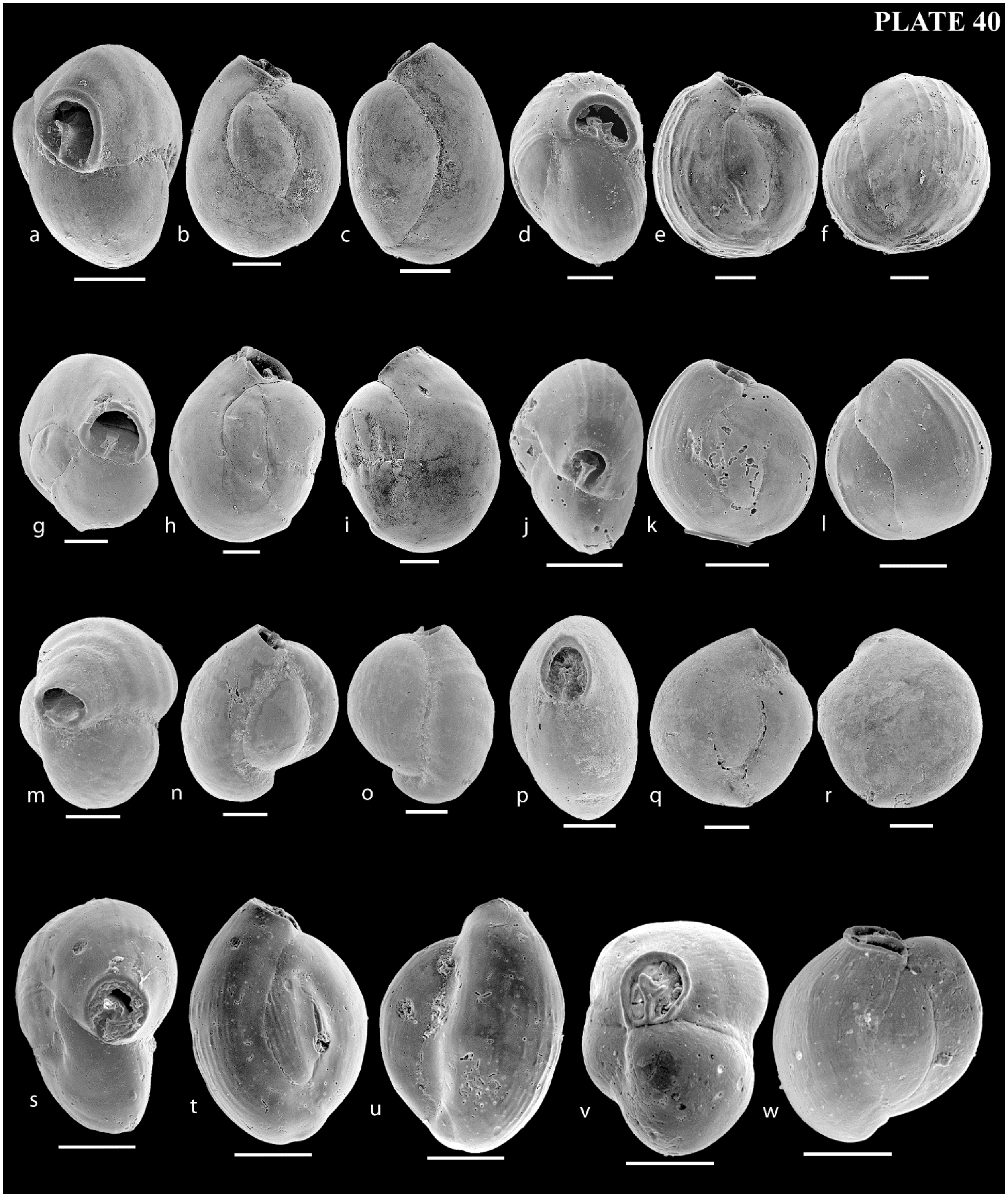
PLATE 40
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PLATE 41 (*Triloculina wiesneri* – *Triloculina* sp. 01)

a–c ***Triloculina wiesneri*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Triloculina* sp. 6** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Triloculina fichteliana*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Triloculina fichteliana*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Triloculina* sp. 2** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Triloculina* sp.** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Triloculina* sp. 3** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Triloculina* sp. 1** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

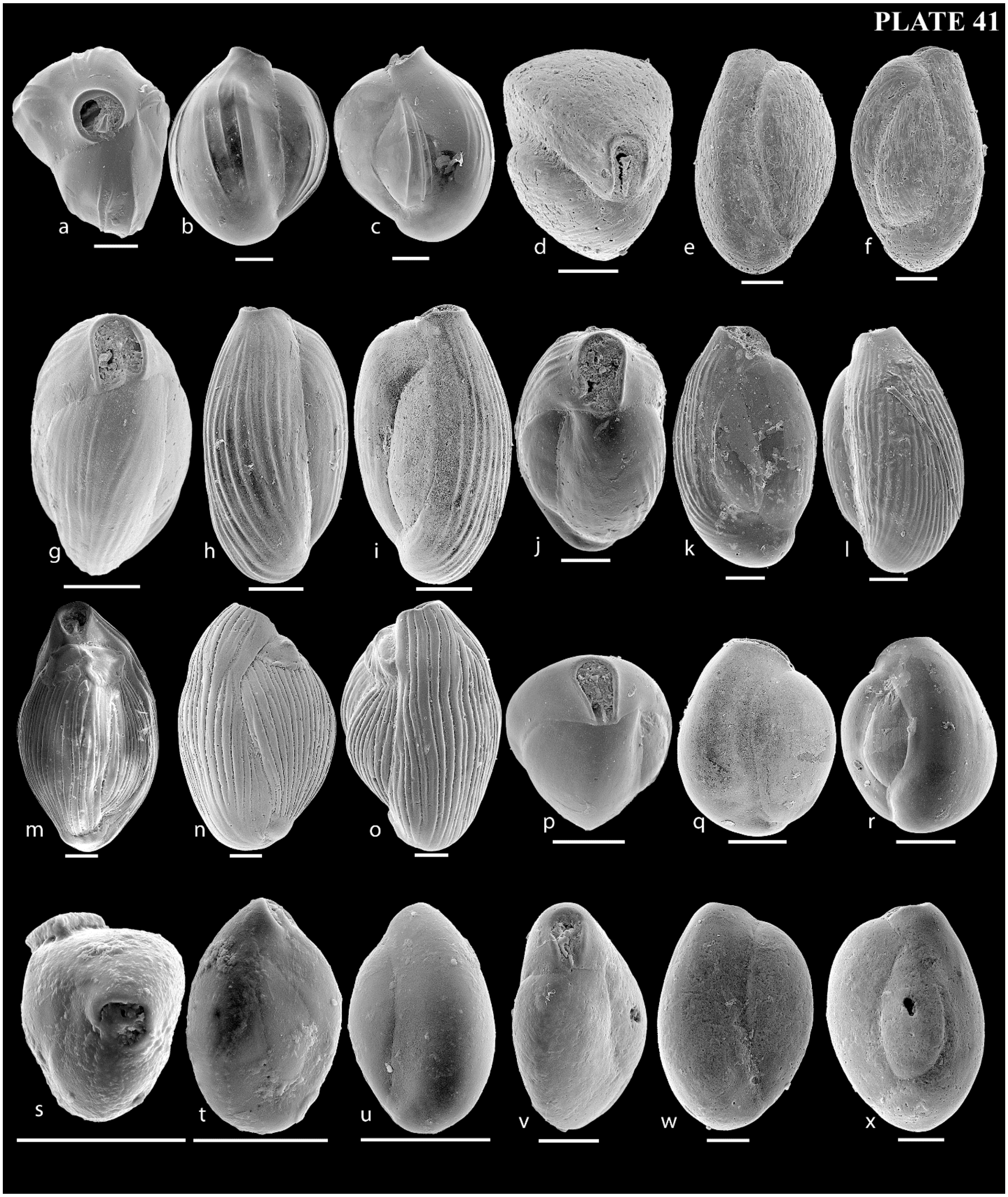
PLATE 41
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PLATE 42 (*Triloculina tricarinata – Triloculina trigonula*)

a–c ***Triloculina tricarinata*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–e ***Triloculina trigonula*** (d) apertural view (e) lateral view.

f–h ***Triloculina* cf. *T. trigonula*** (f) apertural view (g) lateral view (h) lateral view of the opposite side.

i–j ***Triloculina* cf. *T. trigonula*** (j) apertural view (k) lateral view

k–m ***Triloculina trigonula*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

n–p ***Triloculina* cf. *T. trigonula*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

q–s ***Triloculina plicata*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

t–v ***Triloculina trigonula*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

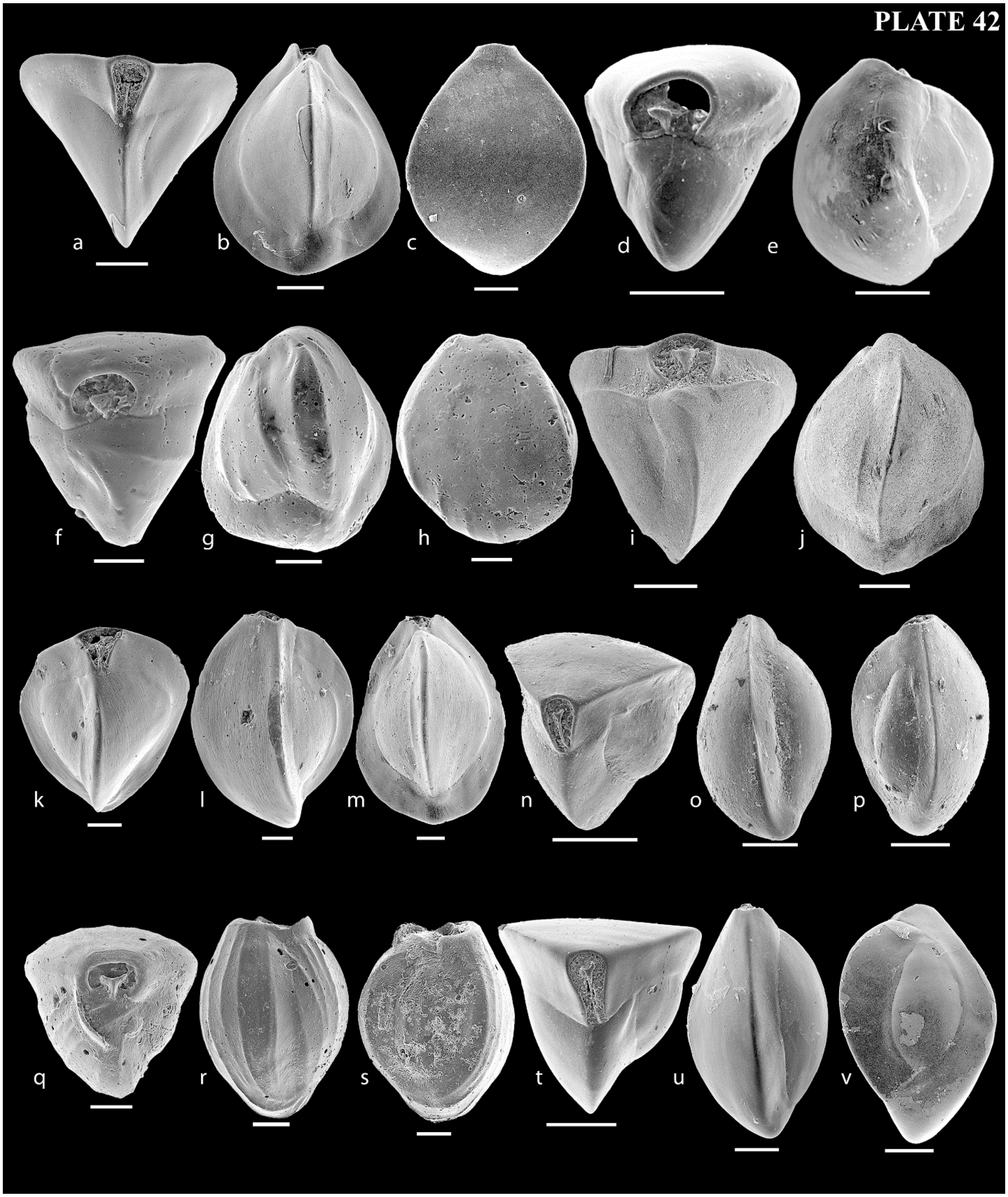
PLATE 42
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PLATE 43 (*Triloculina terquemiana – Triloculina elongotricarinata)*

a–c ***Triloculina terquemiana*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Triloculina terquemiana*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Triloculina terquemiana*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Triloculina terquemiana*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Triloculina* cf. *T. affinis*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Triloculina* sp. 4** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Triloculina elongotricarinata*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–w ***Triloculina elongotricarinata*** (v) apertural view (w) lateral view.

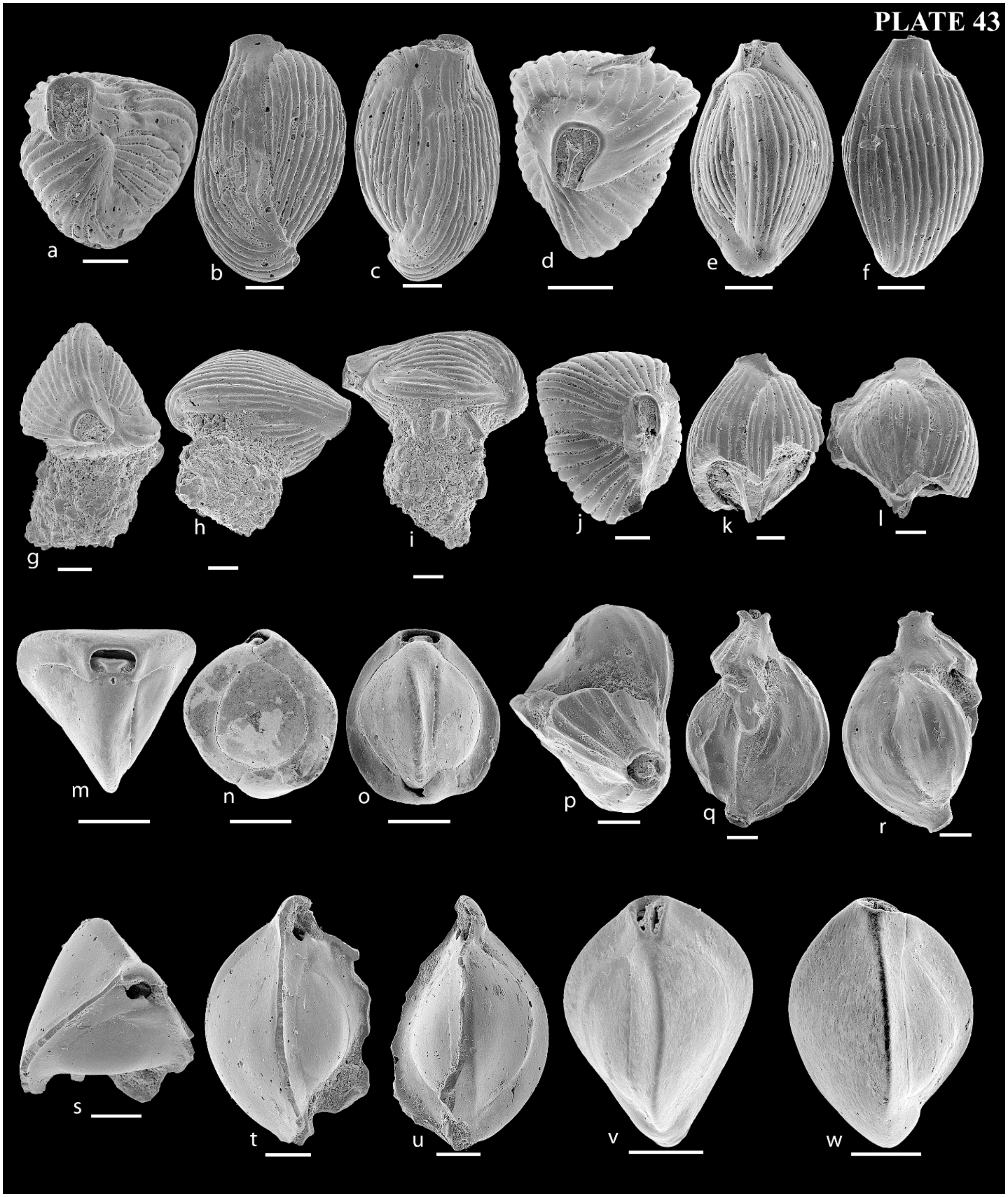
PLATE 43
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PLATE 44 (*Spiroloculina indica – Spiroloculina attenuata)*

a–c ***Spiroloculina indica*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Spiroloculina indica*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Spiroloculina indica*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Spiroloculina indica*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Spiroloculina indica*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Spiroloculina* sp. 4** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Spiroloculina* sp. 1** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Spiroloculina attenuata*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

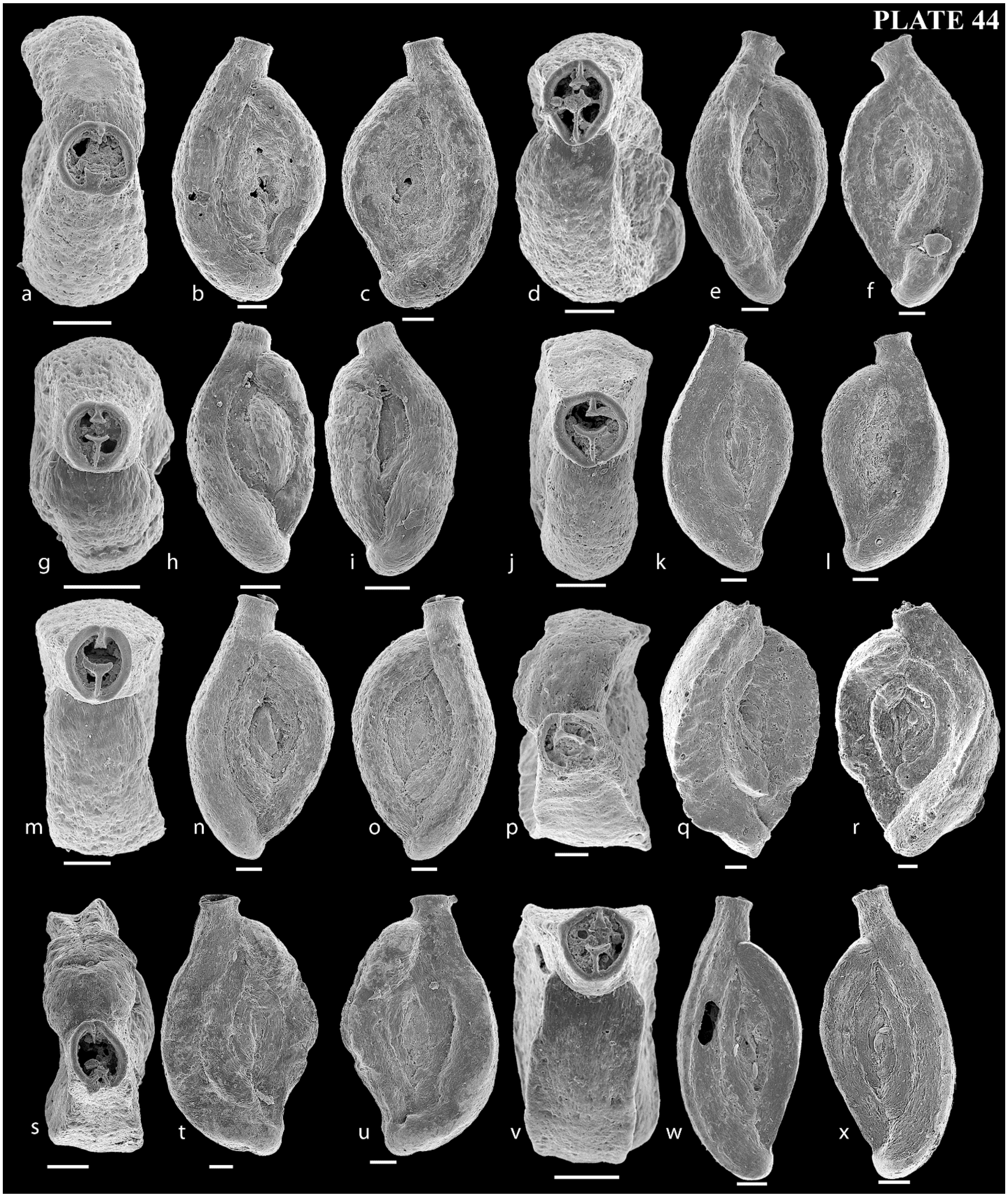
PLATE 44
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PLATE 45 (*Spiroloculina communis – Spiroloculina rotunda)*

a–c ***Spiroloculina communis*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Spiroloculina* sp. 9** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Spiroloculina rotunda*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Spiroloculina rotunda*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Spiroloculina rotunda*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Spiroloculina rotunda*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Spiroloculina rotunda*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Spiroloculina rotunda*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

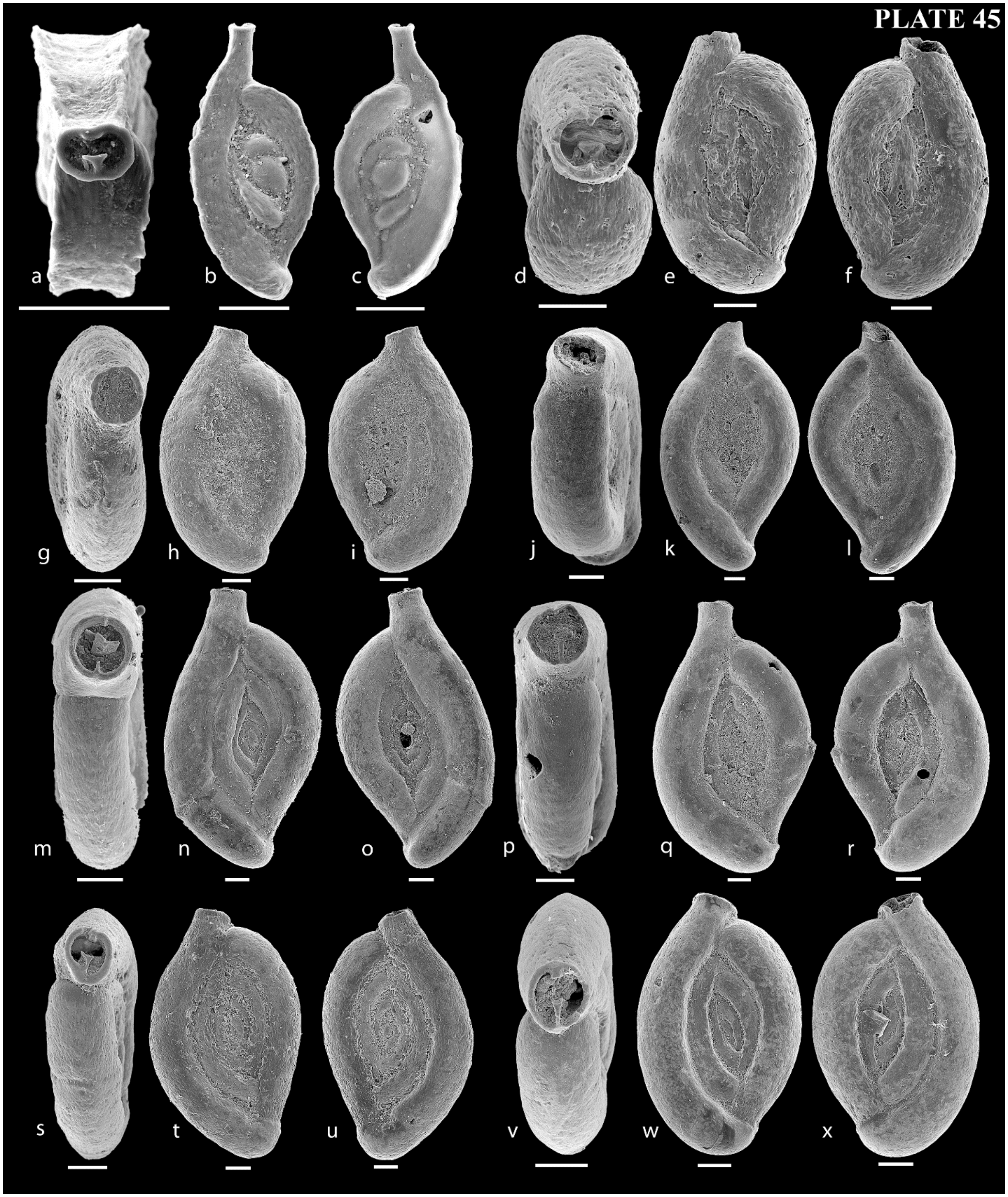
PLATE 45
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PLATE 46 (*Spiroloculina rotunda* – *Spiroloculina* sp. 07)

a–c ***Spiroloculina rotunda*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Spiroloculina rotunda*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Spiroloculina rotunda*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Spiroloculina* sp. 2** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Spiroloculina excavata*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Spiroloculina* sp. 8** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Spiroloculina communis*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Spiroloculina* sp. 7** (v) apertural view (w) lateral view (x) lateral view of the opposite side.


PLATE 46
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PLATE 47 (*Spiroloculina* cf. *S. depressa* – *Spiroloculina* cf. *S. nummiformis)*

a–c ***Spiroloculina* cf. *S. depressa*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Spiroloculina* cf. *S. depressa*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Spiroloculina* sp. 5** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Spiroloculina* sp. 2** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Spiroloculina* sp. 4** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Spiroloculina* sp. 8** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Spiroloculina pulchella*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–w ***Spiroloculina* cf. *S. nummiformis*** (v) apertural view (w) lateral view.

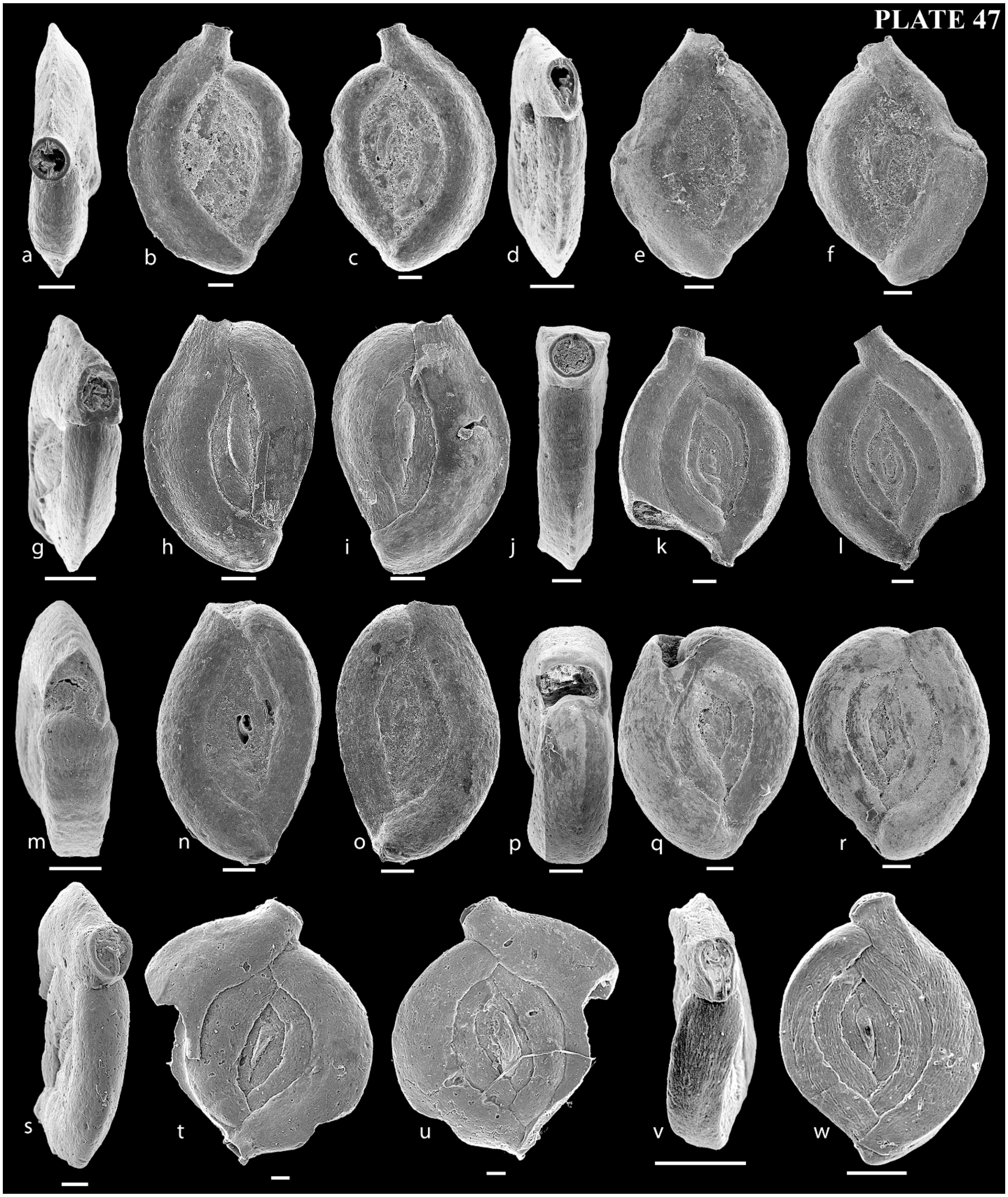
PLATE 47
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PLATE 48 (*Spiroloculina* cf. *S. communis – Spiroloculina subimpressa)*

a–c ***Spiroloculina* cf. *S. communis*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Spiroloculina* sp. 5** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Spiroloculina* sp. 1** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Spiroloculina* sp. 10** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Spiroloculina* sp. 3 *(***m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Spiroloculina subimpressa*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Spiroloculina subimpressa*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Spiroloculina subimpressa*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

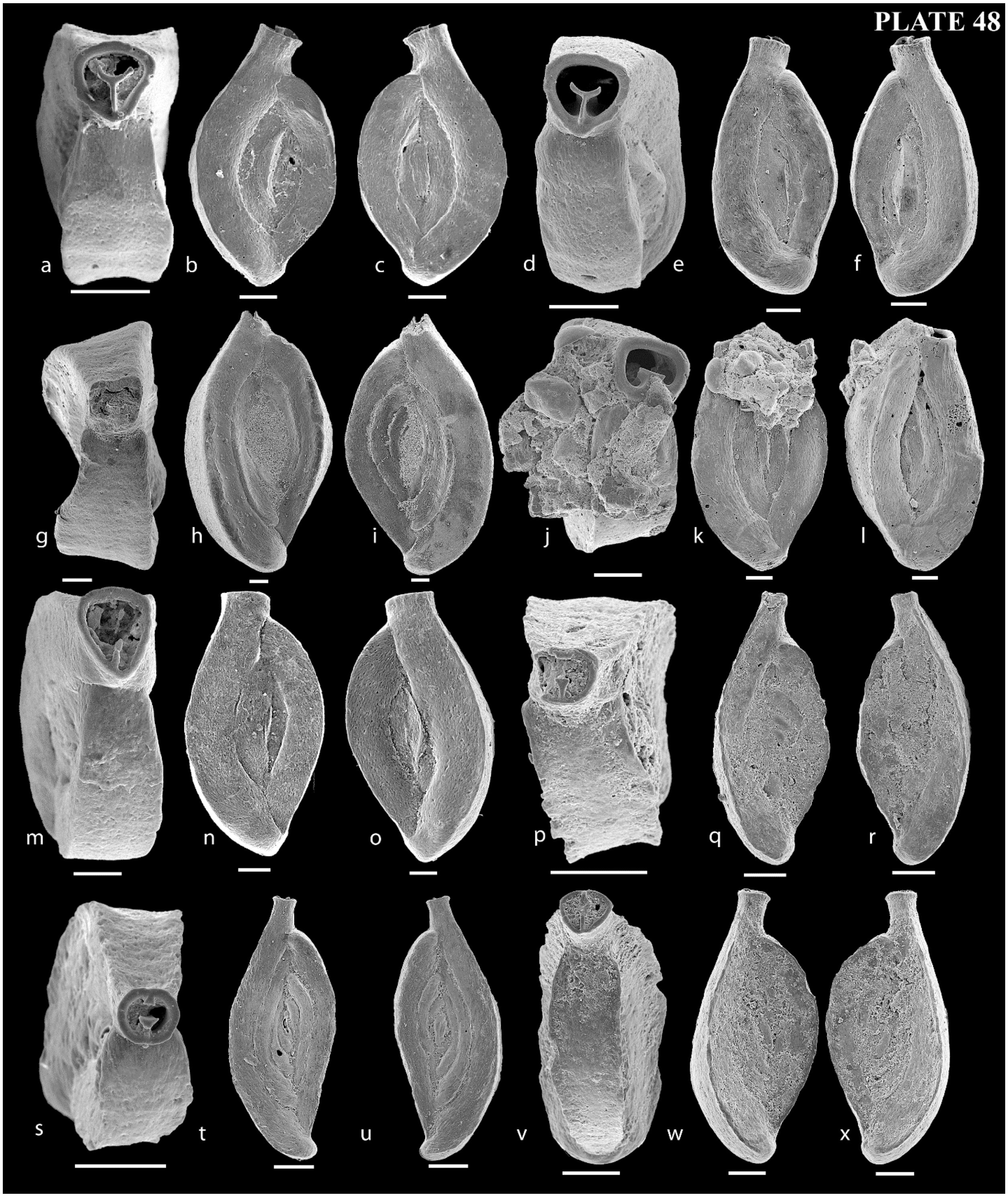
PLATE 48
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PLATE 49 (*Spiroloculina* sp. 06 – *Spiroloculina regularis*)

a–c ***Spiroloculina* sp. 6** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Spiroloculina* sp. 3** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Spiroloculina hadai*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Spiroloculina elegantissima*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–n ***Spiroloculina regularis*** (m) apertural view (n) lateral view.

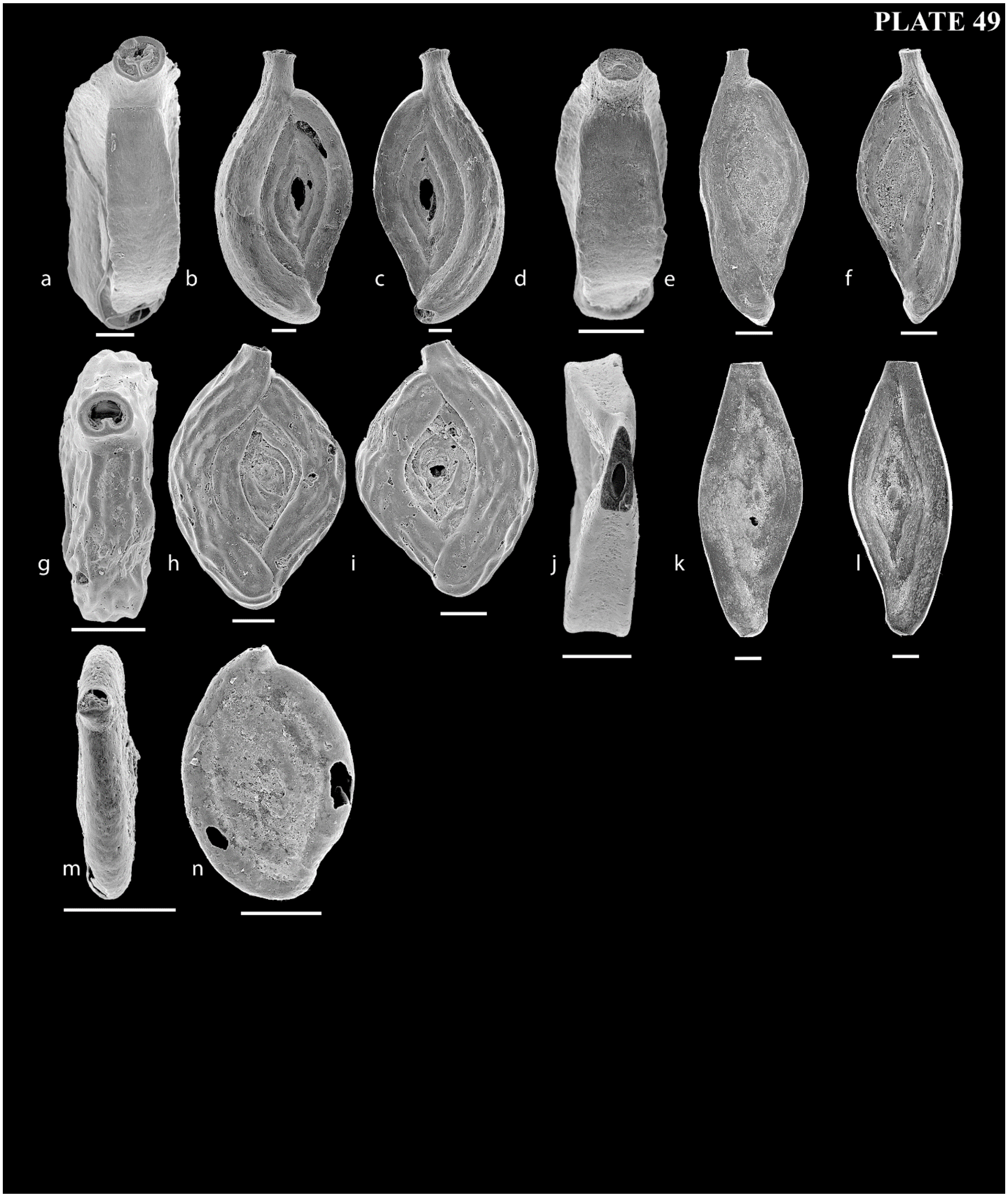
PLATE 49
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PLATE 50 (*Adelosina* sp. 1 – *Adelosina* sp. 1)

a–c ***Adelosina* sp. 1** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Adelosina* sp. 3** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Adelosina* sp. 2** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Adelosina laevigata*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Adelosina* sp. 5** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Adelosina* sp. 2** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Adelosina* sp. 4** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Adelosina* sp. 10** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

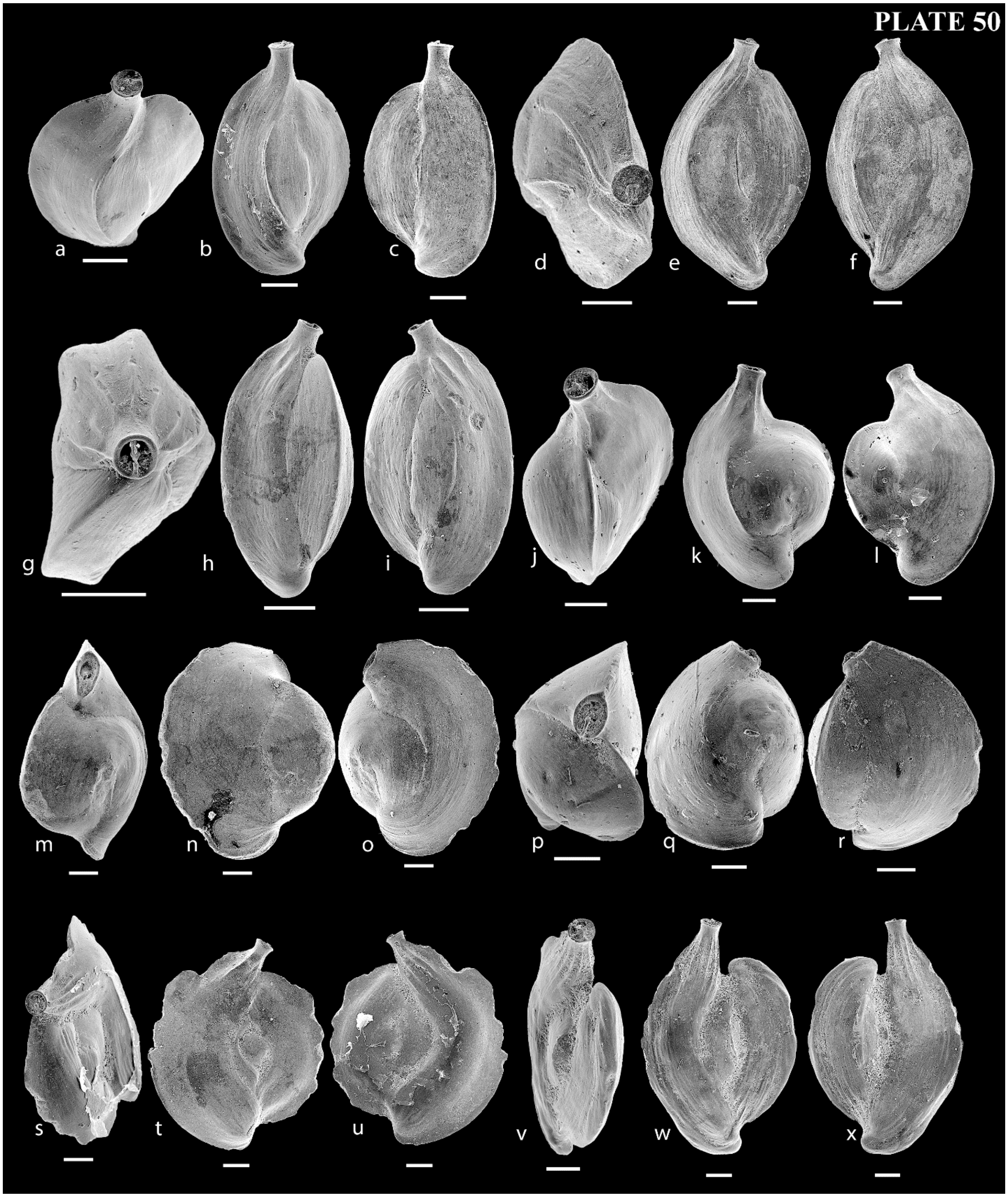
PLATE 50
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PLATE 51 (*Adelosina* cf. *A. mediterranensis* – *Milolinella* cf. *M. hybrid)*

a–c ***Adelosina* cf. *A. mediterranensis*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Adelosina mediterranensis*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Adelosina* sp. 7** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Adelosina* sp. 1** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Adelosina* sp. 6** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Pygro phlegeri*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Pygro sarsi*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–w ***Milolinella* cf. *M. hybrida*** (v) apertural view (w) lateral view.

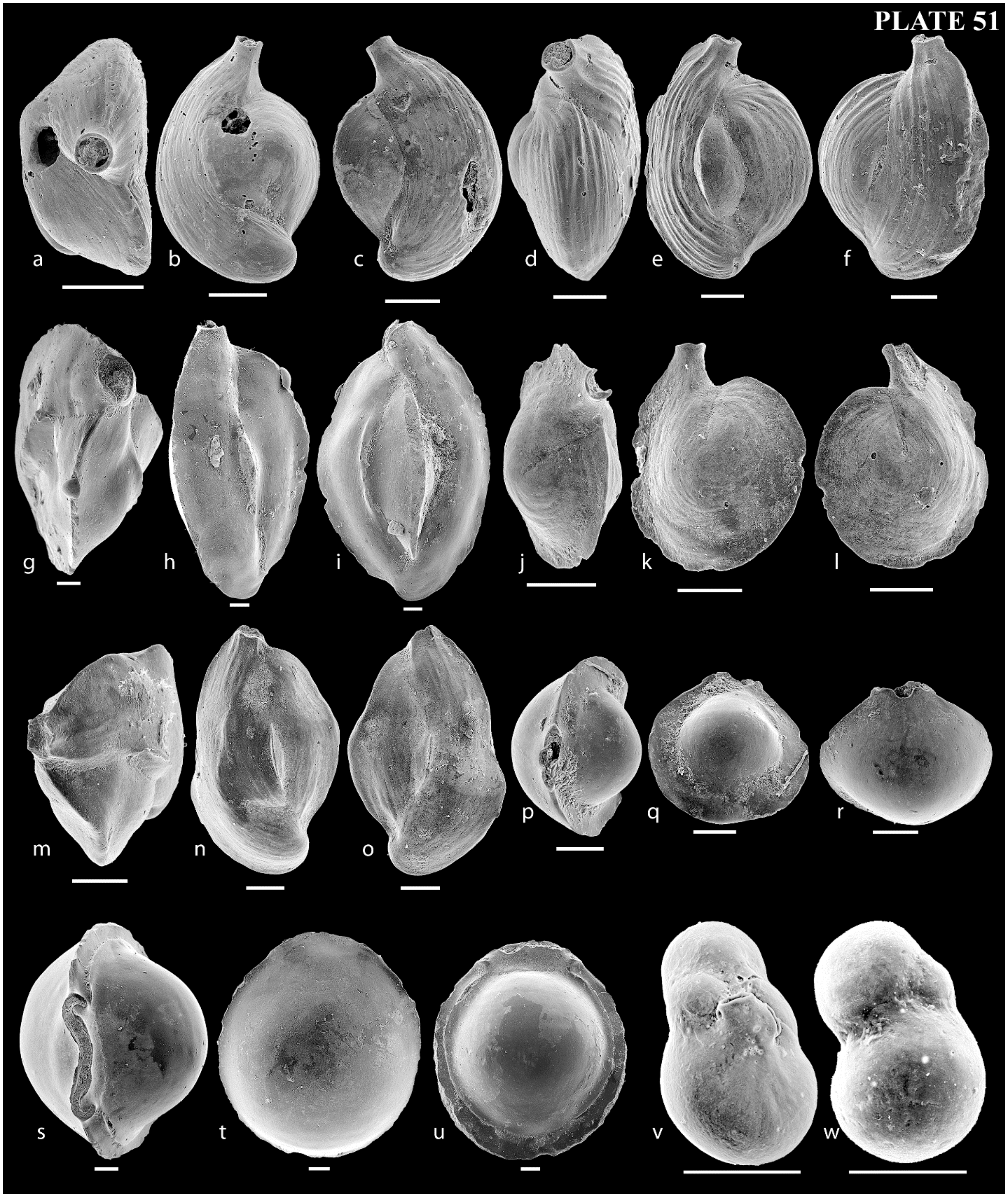
PLATE 51
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PLATE 52 (*Miliolinella* cf. *M. hybrid* – *Miliolinella* cf. *M. circularis)*

a–c ***Miliolinella* cf. *M. hybrida*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Miliolinella* cf. *M. hybrida*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Miliolinella* cf. *M. hybrida*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Miliolinella* cf. *M. hybrida*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Miliolinella* sp. 4** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Miliolinella* sp. 2** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Miliolinella* sp. 3** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Miliolinella* cf. *M. circularis*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

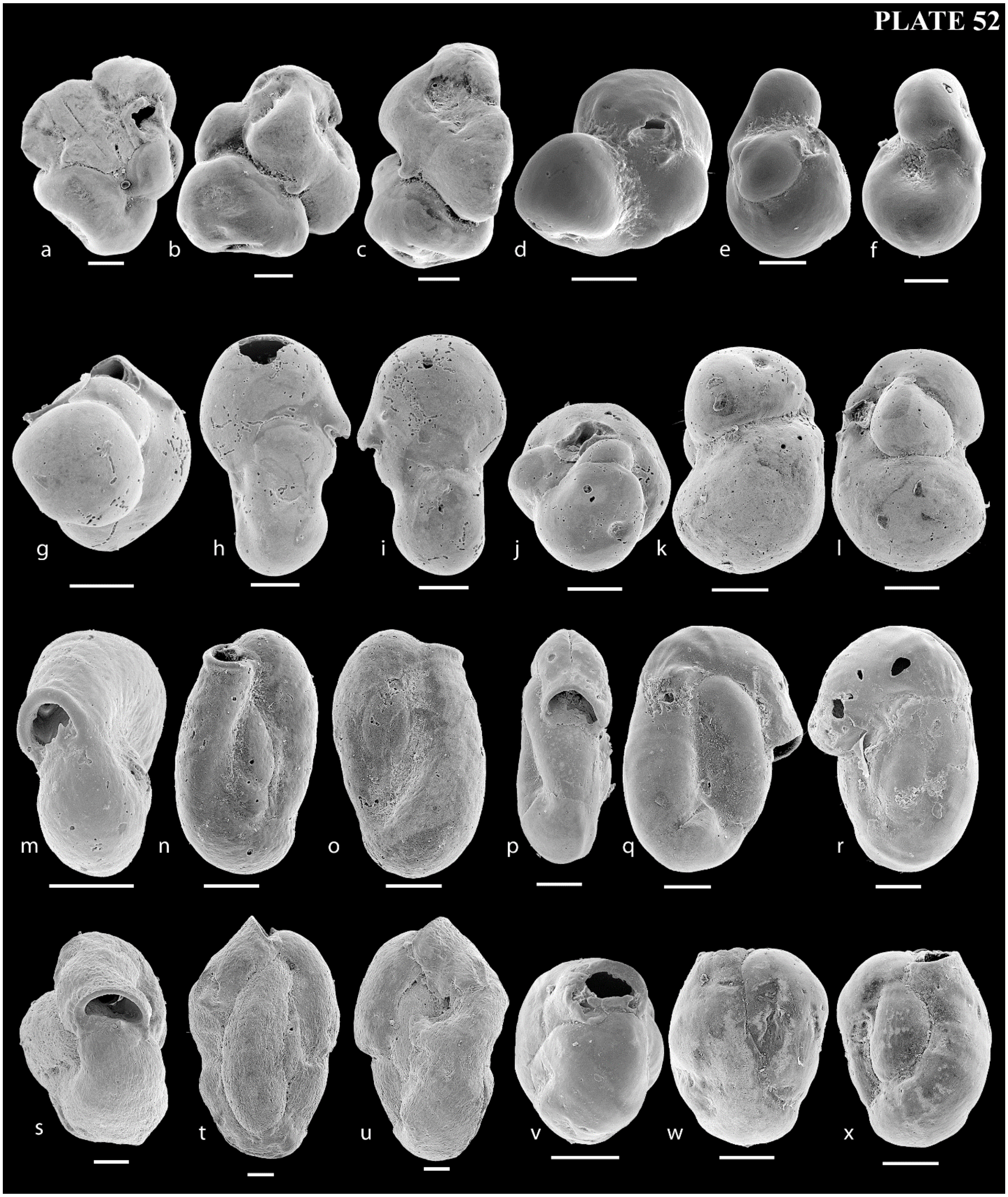
PLATE 52
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PLATE 53 (*Miliolinella chuckchiensis* – *Pseudotriloculina* sp.)

a–c ***Miliolinella chuckchiensis*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Miliolinella chuckchiensis*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Miliolinella* sp. 3** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Miliolinella chuckchiensis*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Sigmamiliolinella australis*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Flintina* sp. 1** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Flintina* sp. 2** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Pseudotriloculina* sp.** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

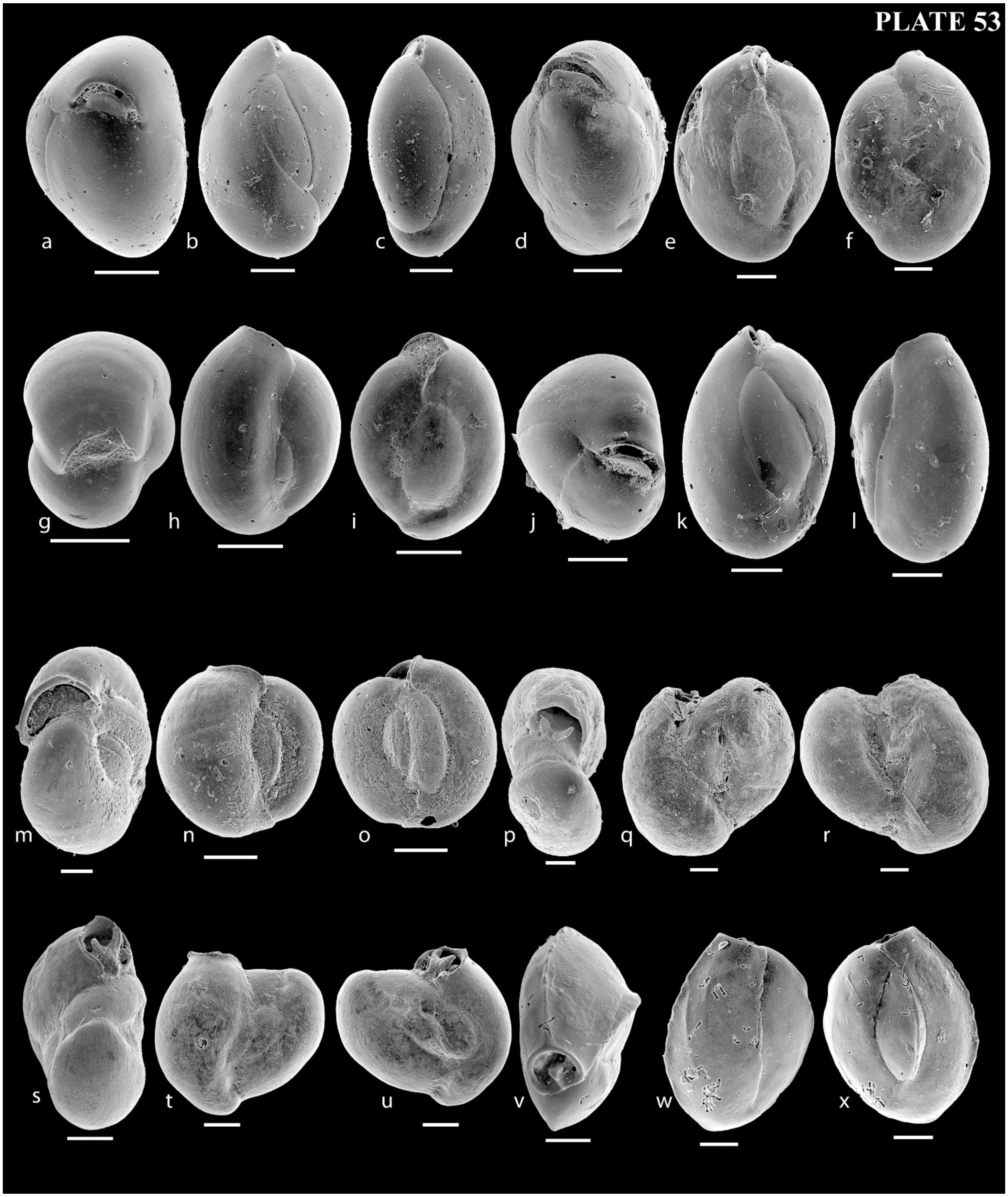
PLATE 53
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PLATE 54 (*Lachnella subpolygona – Pseudotriloculina hottingeri)*

a–c ***Lachnella subpolygona*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina* cf. *Q. distorqueata*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Lachlanella corrugata*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Pseudotriloculina hottingeri*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Pseudotriloculina hottingeri*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Pseudotriloculina hottingeri*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Pseudotriloculina hottingeri*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Pseudotriloculina hottingeri*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

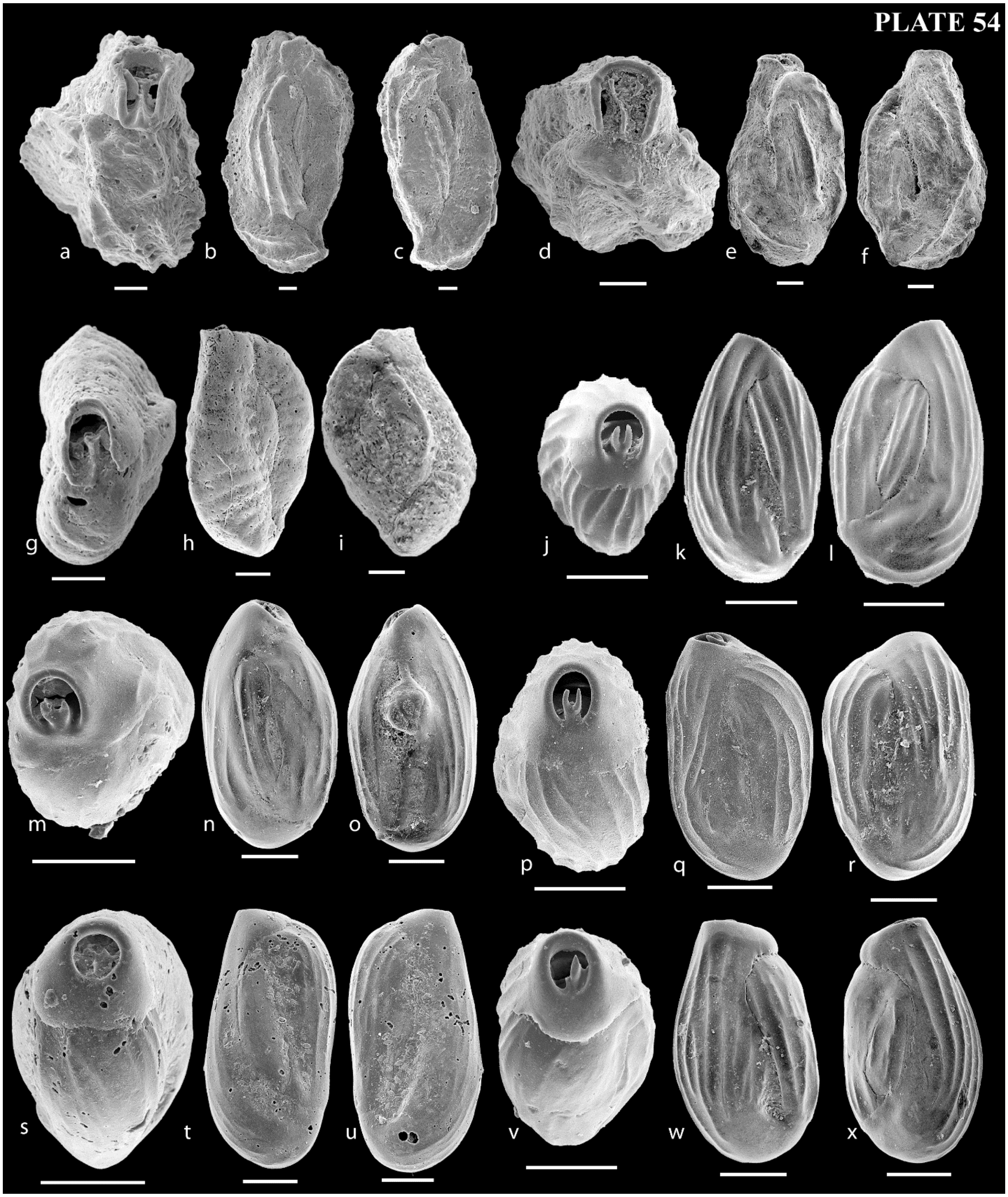
PLATE 54
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PLATE 55 (*Pseudotriloculina subgranulata – Quinqueloculina* sp.)

a–c ***Pseudotriloculina subgranulata*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–e ***Pseudotriloculina subgranulata*** (d) apertural view (e) lateral view.

f–h ***Pseudotriloculina subgranulata*** (g) apertural view (g) lateral view (h) lateral view of the opposite side.

i–k ***Pseudotriloculina subgranulata*** (i) apertural view (j) lateral view (k) lateral view of the opposite side.

l–n ***Cycloforina carinata*** (l) apertural view (m) lateral view (n) lateral view of the opposite side.

o–q ***Cycloforina quinquecarinata*** (o) apertural view (p) lateral view (q) lateral view of the opposite side.

r–t ***Quinqueloculina* sp.** (r) apertural view (s) lateral view (t) lateral view of the opposite side.

u–v ***Quinqueloculina* sp.** (u) apertural view (v) lateral view.

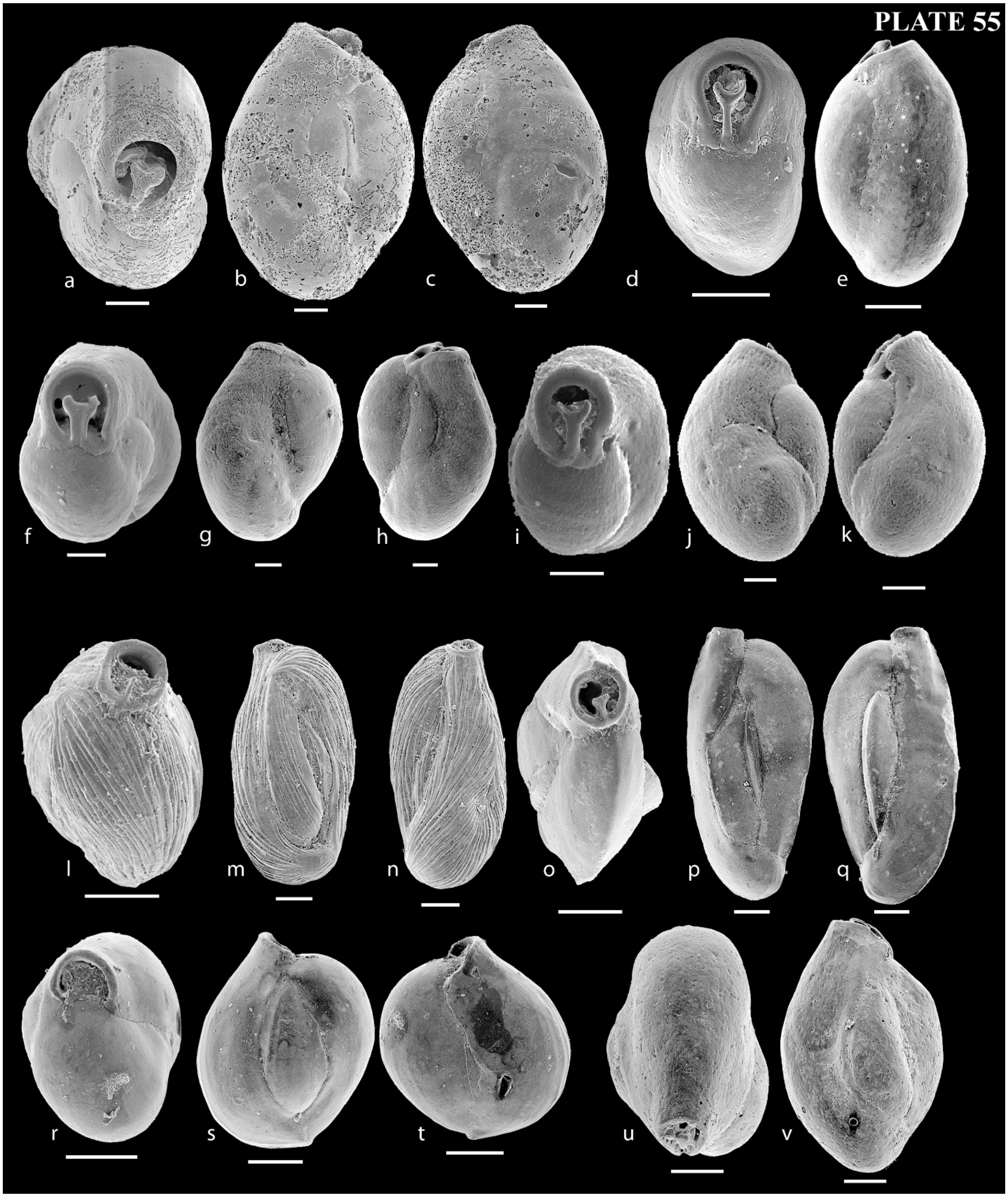
PLATE 55
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PLATE 56 (*Coscinospira arienatus – Coscinospira hemprichii)*

a–c ***Coscinospira arienatus*** (a) apertural view (b) lateral view (c) lateral view of the opposite side (d) zoomed view of the pores on the surfaces of (a–c).

e–g ***Coscinospira arienatus*** (e) apertural view (f) lateral view (g) lateral view of the opposite side.

h–j ***Coscinospira arienatus*** (h) apertural view (i) lateral view (j) lateral view of the opposite side.

k–m ***Conscinopira* sp.** (k) apertural view (l) lateral view (m) lateral view of the opposite side.

n–o ***Coscinospira hemprichii*** (n) apertural view (o) lateral view.

p–q ***Coscinospira hemprichii*** (p) apertural view (q) lateral view.

r–t ***Coscinospira hemprichii*** (s) apertural view (t) lateral view (t) zoomed in view of the aperture.

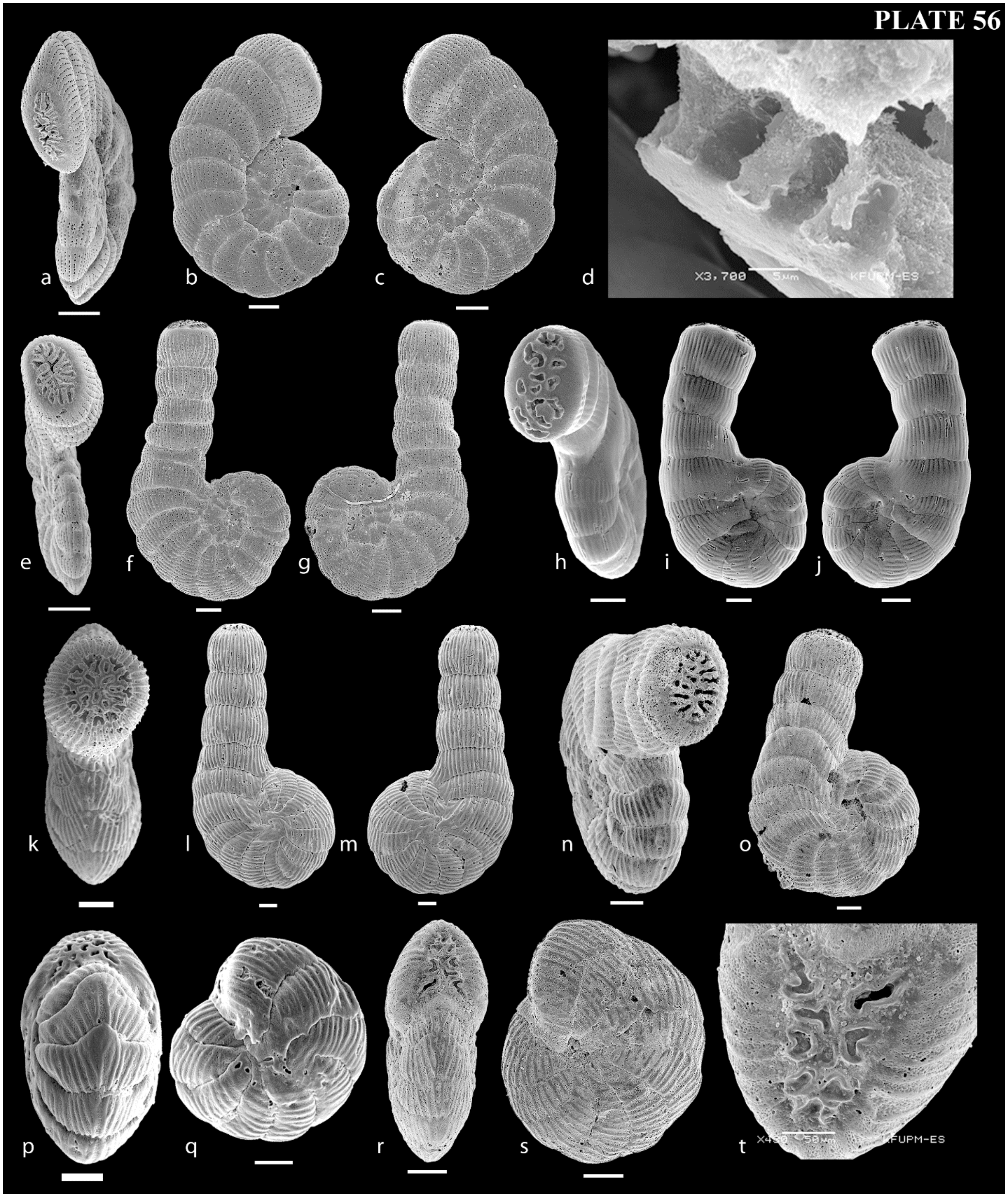
PLATE 56
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KFUPM-ES

PLATE 57 (*Coscinospira hemprichii* – *Peneroplis* sp. 2)

a–c ***Coscinospira hemprichii*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Coscinospira hemprichii*** juvenile (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Peneroplis* sp**. (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Coscinopira* sp.** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–p ***Peneroplis* sp**. (m) apertural view (n) lateral view (o) lateral view of the opposite side (p) zoomed in view of the aperture.

q–t ***Peneroplis* sp. 2** (q) apertural view (r) lateral view (s) lateral view of the opposite side (t) zoomed in view of the aperture.

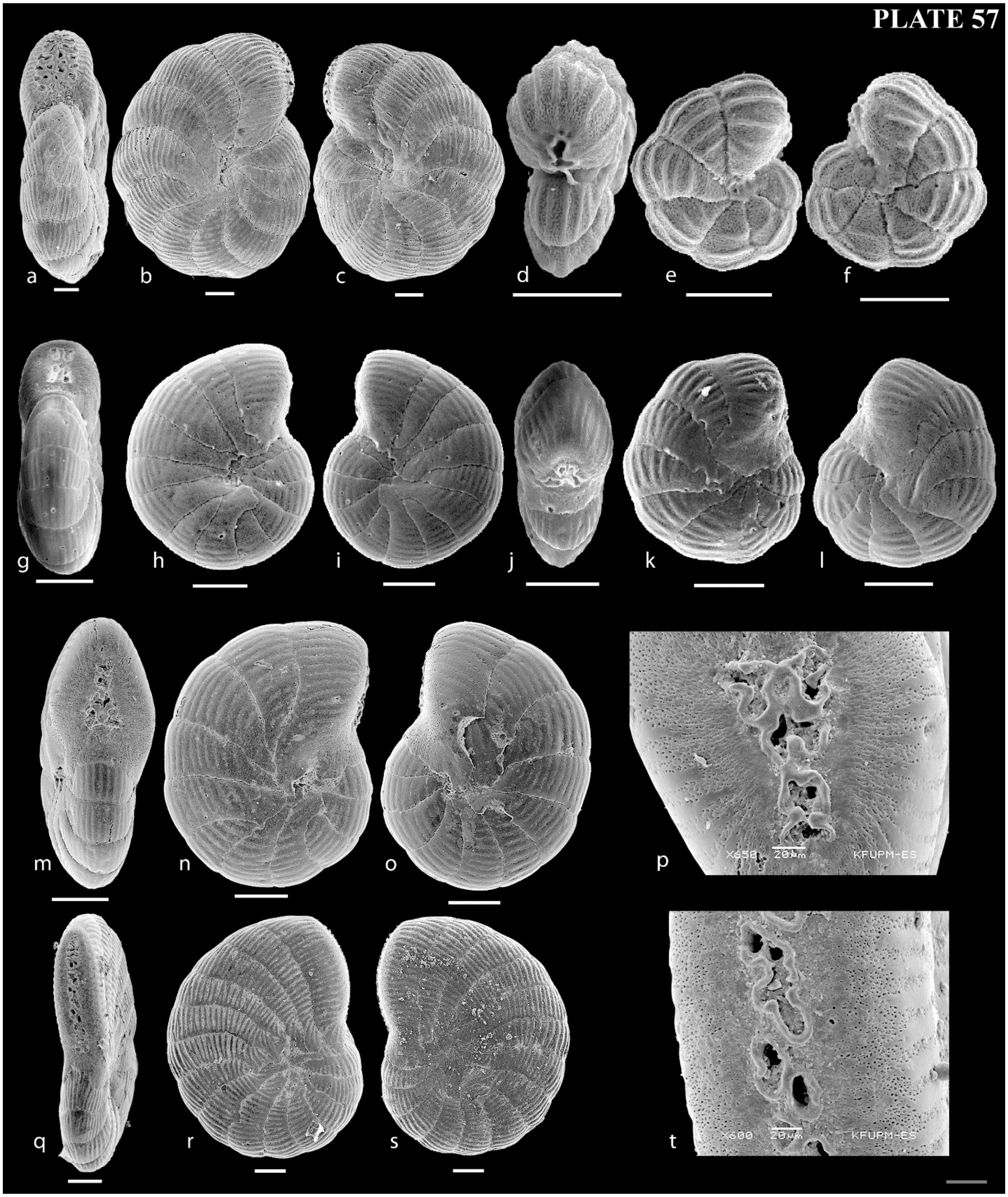
PLATE 57
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X600 20µm KFUPM-ES

PLATE 58 (*Peneroplis planatus – Sorites orbicularis)*

a–c ***Peneroplis planatus*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Peneroplis planatus*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–h ***Articulina alticostata*** (g) apertural view (h) lateral view.

i–k ***Articulina pacifica*** (i) apertural view (j) lateral view (k) lateral view of the opposite side.

l–n ***Vertebralina striata*** (l) apertural view (m) lateral view (n) lateral view of the opposite side.

o–q ***Vertebralina striata*** (o) apertural view (p) lateral view (q) lateral view of the opposite side.

r–t ***Sorites orbicularis*** (r) apertural view (s) lateral view (t) lateral view of the opposite side.

u–w ***Sorites orbicularis*** (u) apertural view (v) lateral view (w) lateral view of the opposite side.


PLATE 58
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PLATE 59 (*Quinqueloculina* sp. 07 – *Quinqueloculina* sp. 18)

a–c ***Quinqueloculina* sp. 7** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina* sp. 8** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina* sp. 9** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina* sp. 16** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina* sp. 25** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* sp. 16** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Quinqueloculina* sp. 21** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Quinqueloculina* sp. 18** (v) apertural view (w) lateral view (x) lateral view of the opposite side.


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PLATE 60 (*Quinqueloculina* sp. 19 – *Quinqueloculina* sp. 27)

a–c ***Quinqueloculina* sp. 19** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina* sp. 16** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina* sp. 3** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina* sp. 17** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina* sp. 22** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* sp. 16** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Quinqueloculina* sp. 24** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Quinqueloculina* sp. 27** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

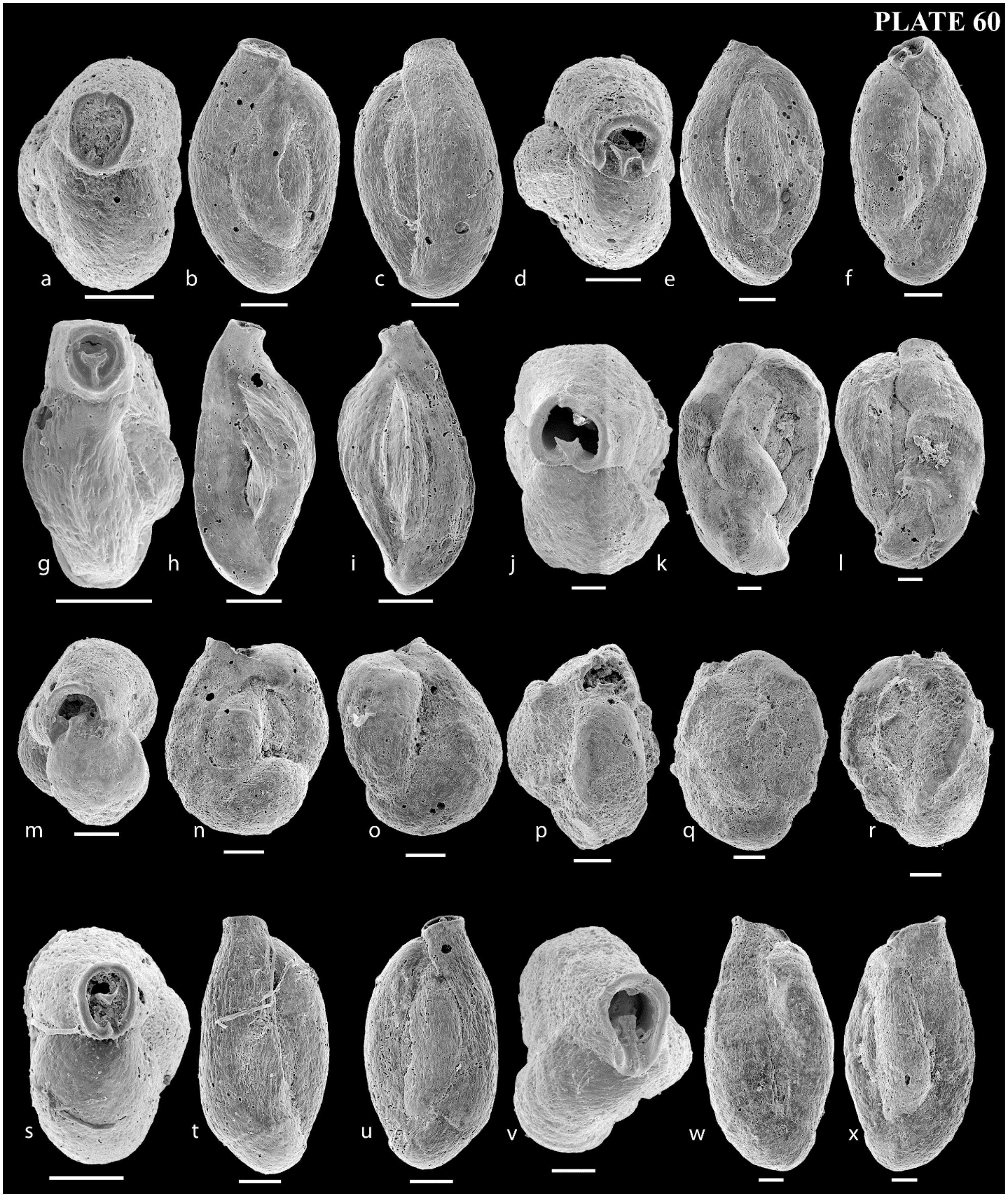
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PLATE 61 (*Quinqueloculina* sp. 31 – *Quinqueloculina* sp. 19)

a–c ***Quinqueloculina* sp. 31** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina timorensis*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina stalkeri*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina* sp. 36** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina* sp. 34** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* sp. 33** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Quinqueloculina* sp. 32** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Quinqueloculina* sp. 19** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

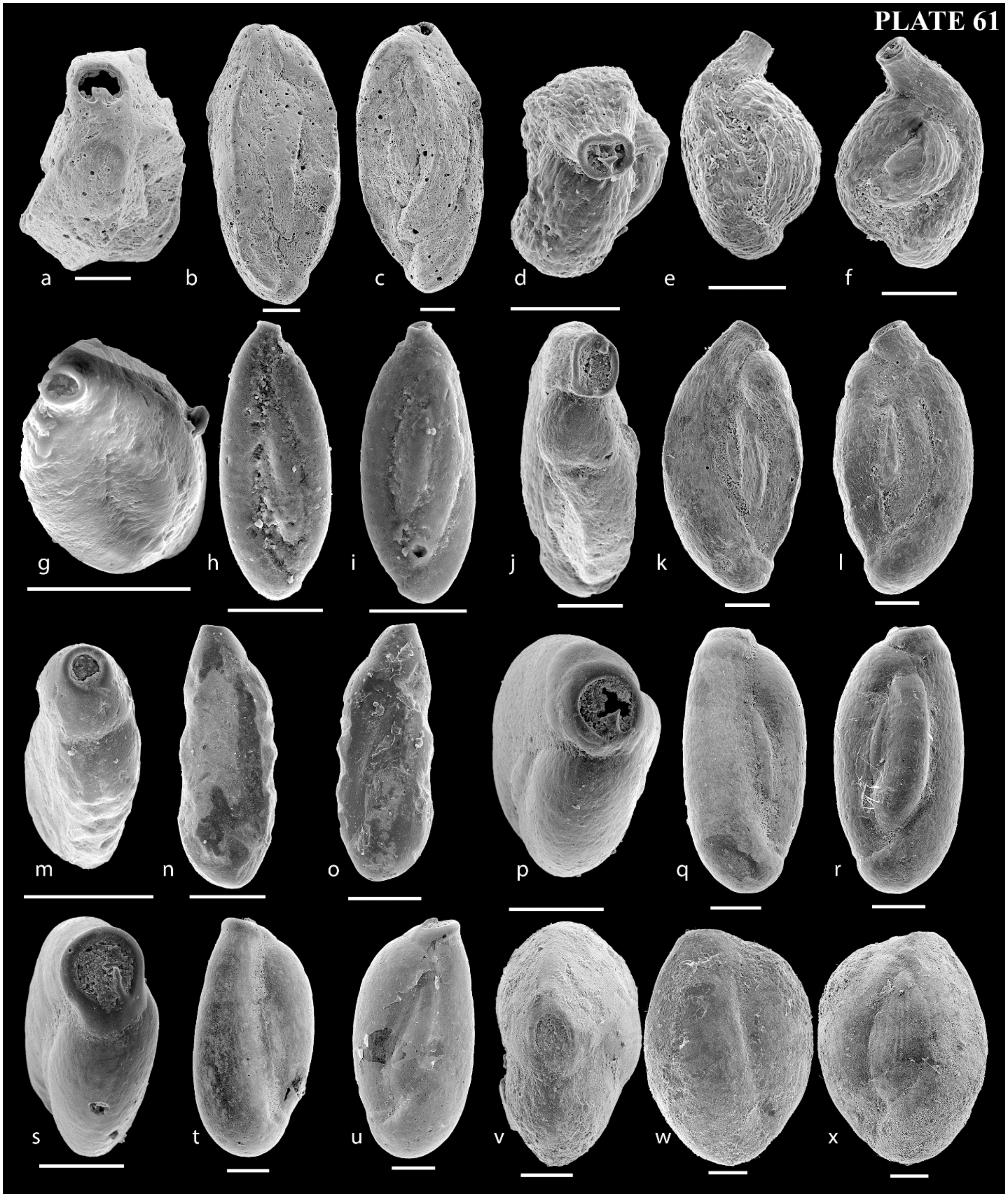
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PLATE 62 (*Quinqueloculina poeyana* – *Quinqueloculina* sp. 40)

a–c ***Quinqueloculina poeyana*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina* sp. 35** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina* sp. 25** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina* sp. 28** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina* sp. 22** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* sp. 21** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Quinqueloculina* sp. 12** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Quinqueloculina* sp. 40** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

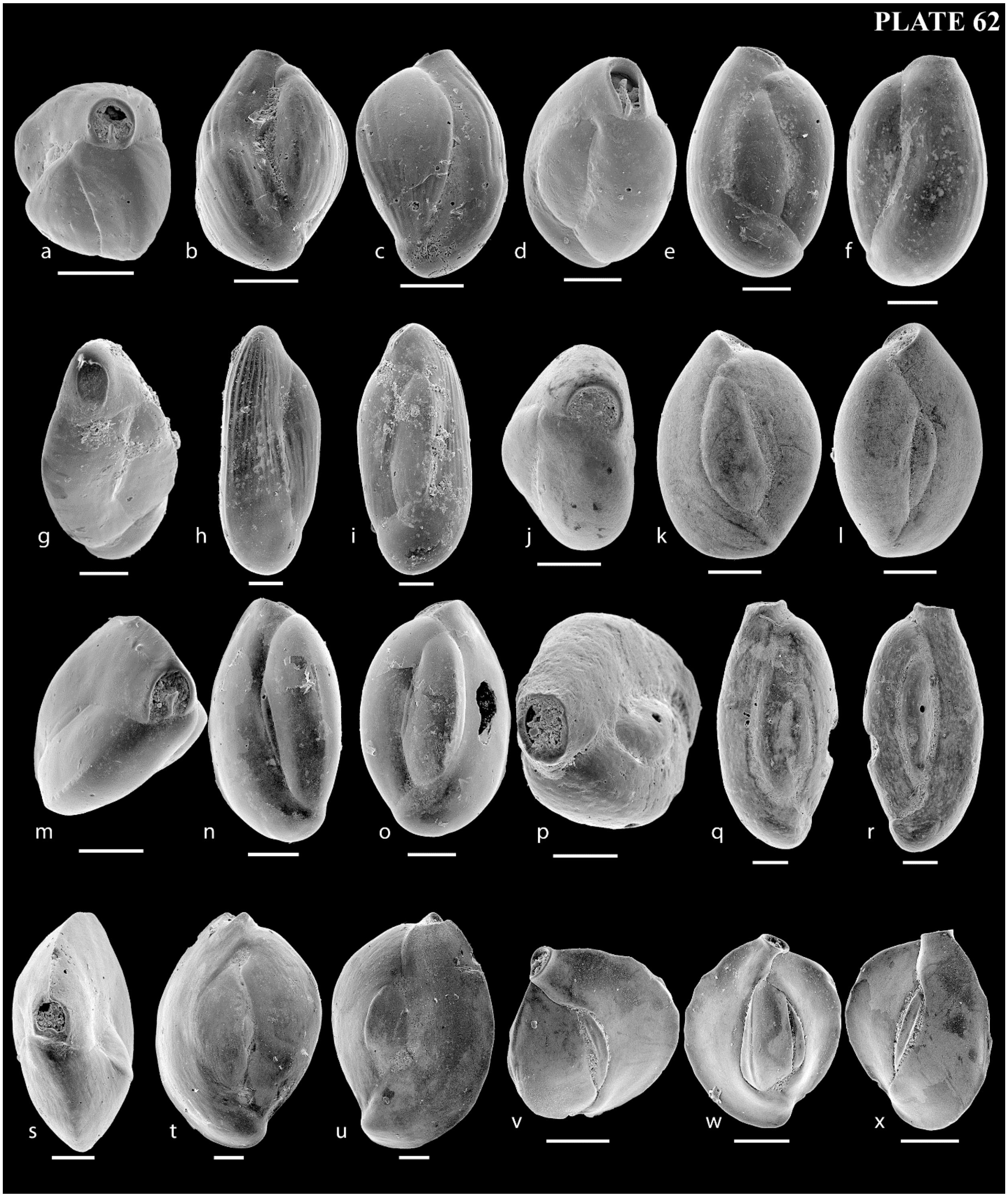
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PLATE 63 (*Quinqueloculina* sp. 30 – *Quinqueloculina* sp. 13)

a–c ***Quinqueloculina* sp. 30** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina* sp. 28** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina* sp. 5** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina* sp. 1** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina* sp. 29** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* sp. 30** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Quinqueloculina* sp. 31** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Quinqueloculina* sp. 13** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

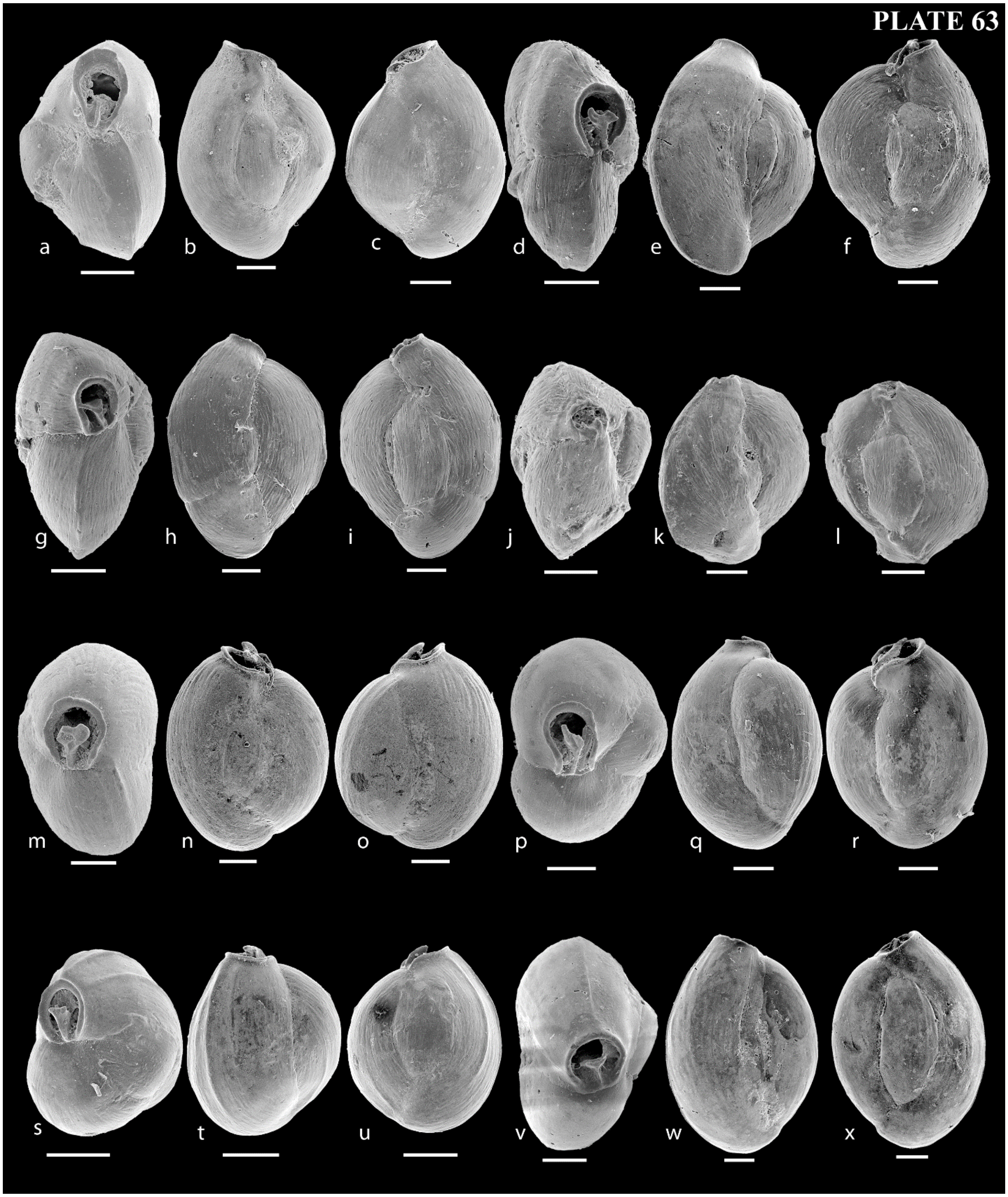
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PLATE 64 (*Quinqueloculina* sp. 1 – *Quinqueloculina* sp. 14)

a–c ***Quinqueloculina* sp. 1** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina* sp. 6** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina lamarckiana*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina* sp. 18** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina* sp. 33** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* sp. 14** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

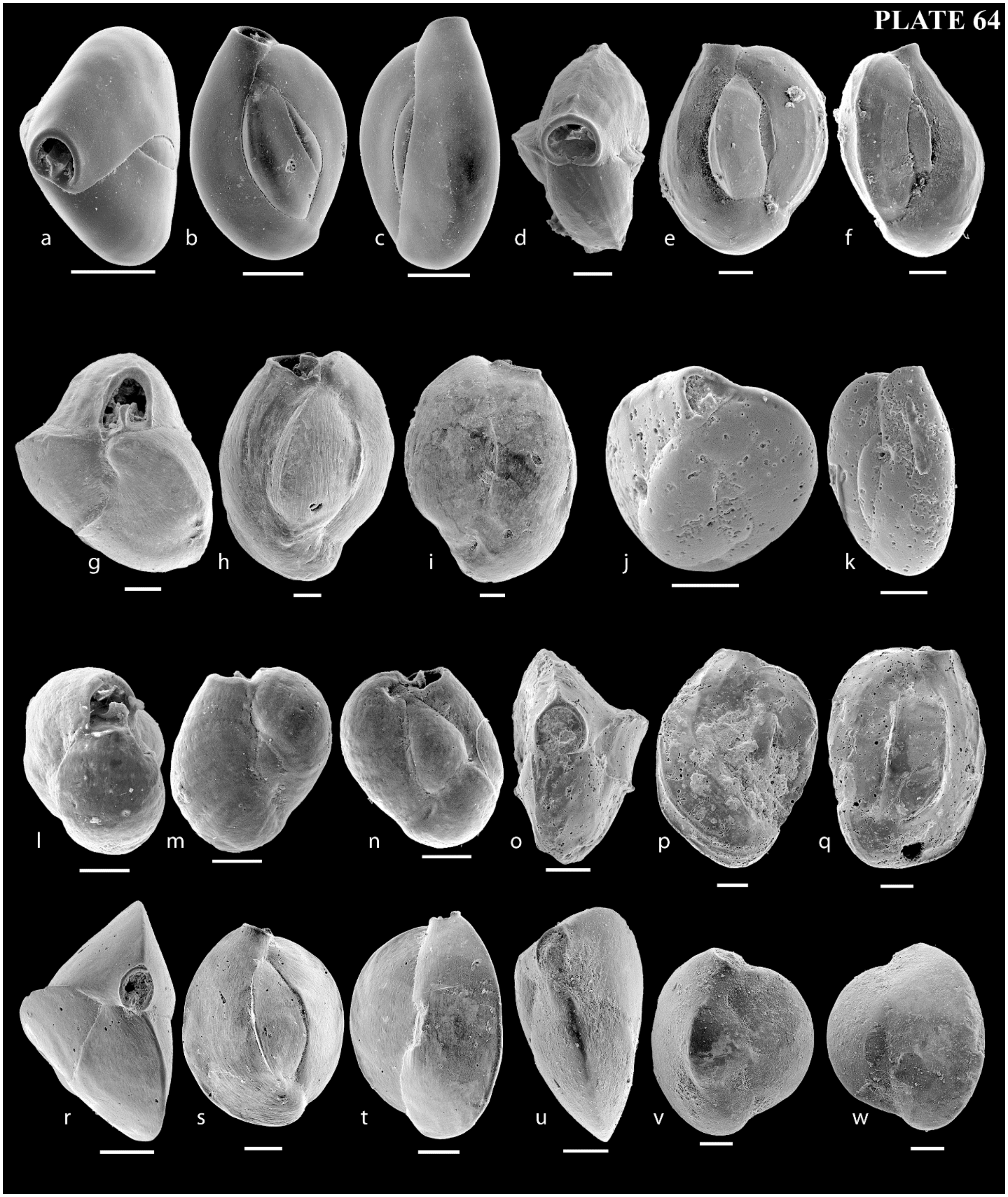
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PLATE 65 (*Quinqueloculina* sp. 20 – *Quinqueloculina seminulum*)

a–c ***Quinqueloculina* sp. 20** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina* sp. 17** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina* sp. 16** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina* sp. 15** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina limbata*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* sp. 32** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Quinqueloculina* sp. 29** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Quinqueloculina seminulum*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

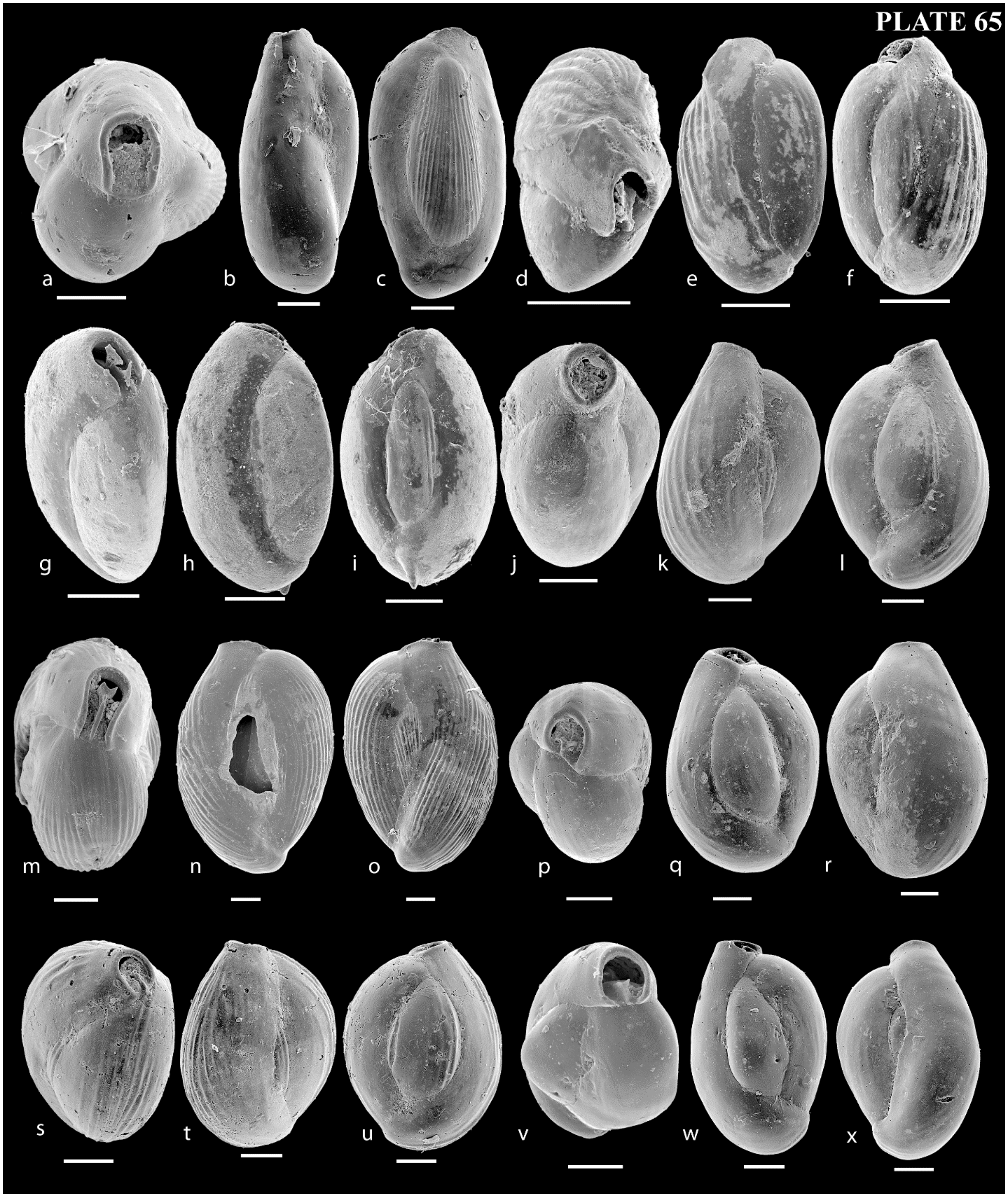
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PLATE 66 (*Quinqueloculina carinatastriata – Quinqueloculina eburnea)*

a–c ***Quinqueloculina carinatastriata*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina carinatastriata*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina carinatastriata*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina carinatastriata*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina carinatastriata*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* cf. *Q. myagmarsuren*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Quinqueloculina* cf. *Q. myagmarsuren*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Quinqueloculina eburnea*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.


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PLATE 67 (*Quinqueloculina akneriana* – *Quinqueloculina* sp.)

a–c ***Quinqueloculina akneriana*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina bosciana*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina* sp.** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina* sp.** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina* sp.** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* sp.** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Quinqueloculina* sp.** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Quinqueloculina* sp.** (v) apertural view (w) lateral view (x) lateral view of the opposite side.


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PLATE 68 (*Quinqueloculina erinacea – Quinqueloculina bidentata)*

a–c ***Quinqueloculina erinacea*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina erinacea*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina* cf. *Q. subcuneata*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina* cf. *Q. subcuneata*** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina* cf. *Q. subcuneata*** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* cf. *Q. subcuneata*** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–t ***Quinqueloculina* sp.** (s) lateral view (t) lateral view of the opposite side.

u–v ***Quinqueloculina granulocosta*** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

w–y ***Quinqueloculina bidentata*** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

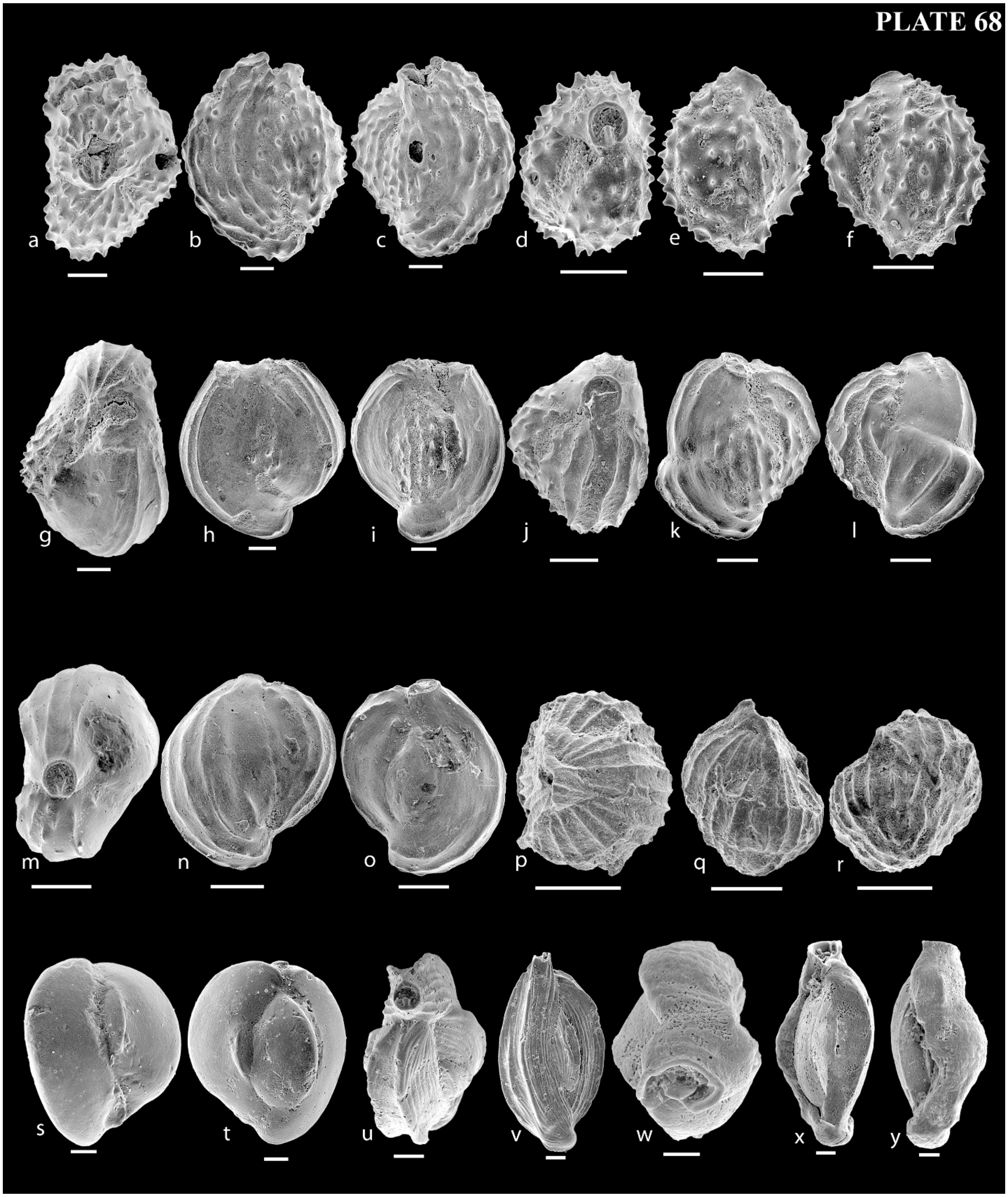
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PLATE 69 (*Quinqueloculina* cf. *Q. quinquecarinata* – *Quinqueloculina* sp. 4)

a–c ***Quinqueloculina* cf. *Q. quinquecarinata*** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina* cf. *Q. quinquecarinata*** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina* cf. *Q. quinquecarinata*** (g) apertural view (h) lateral view (i) lateral view of the opposite side.

j–l ***Quinqueloculina* sp. 13** (j) apertural view (k) lateral view (l) lateral view of the opposite side.

m–o ***Quinqueloculina* sp. 14** (m) apertural view (n) lateral view (o) lateral view of the opposite side.

p–r ***Quinqueloculina* sp. 26** (p) apertural view (q) lateral view (r) lateral view of the opposite side.

s–u ***Quinqueloculina* sp. 27** (s) apertural view (t) lateral view (u) lateral view of the opposite side.

v–x ***Quinqueloculina* sp. 4** (v) apertural view (w) lateral view (x) lateral view of the opposite side.

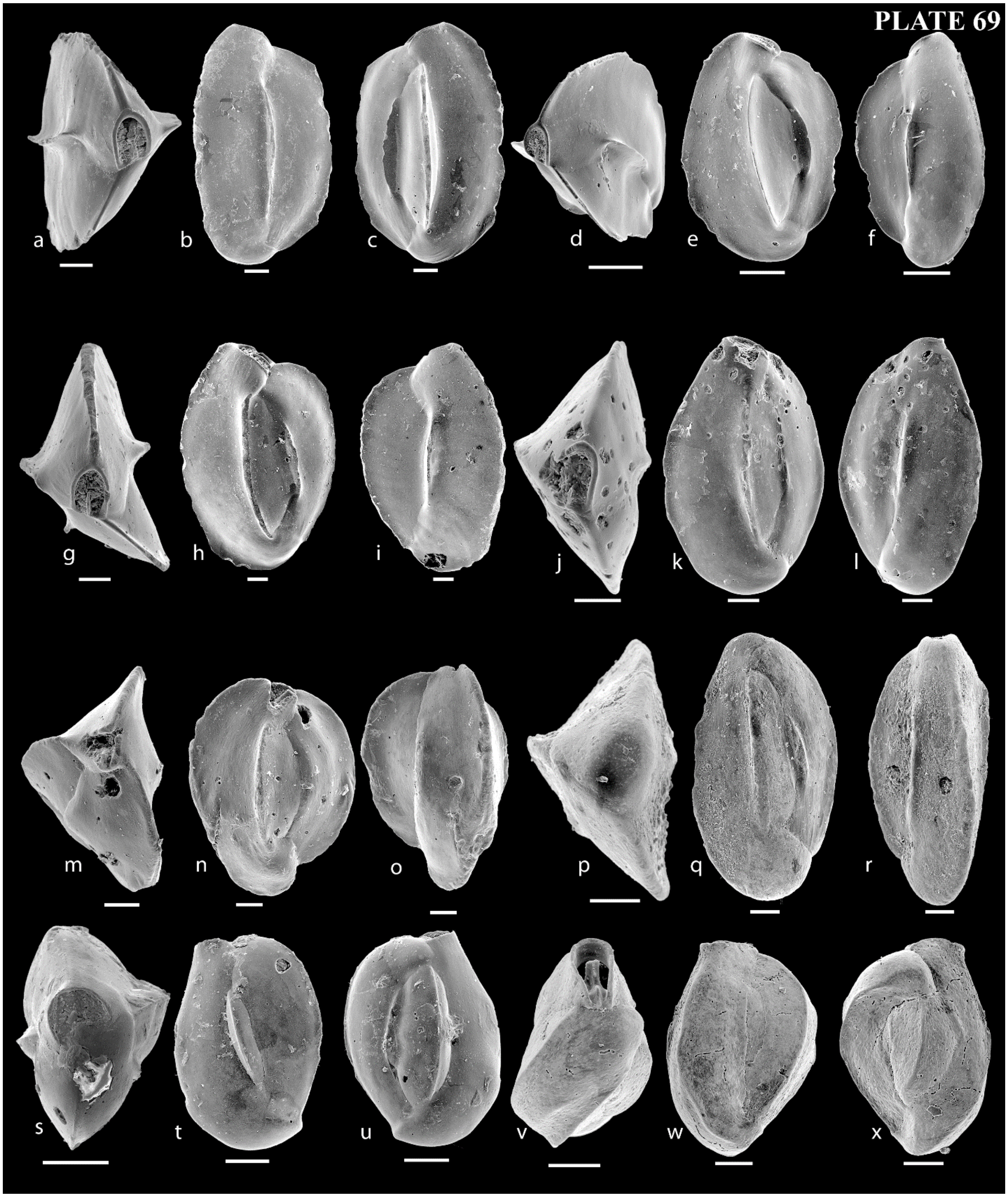
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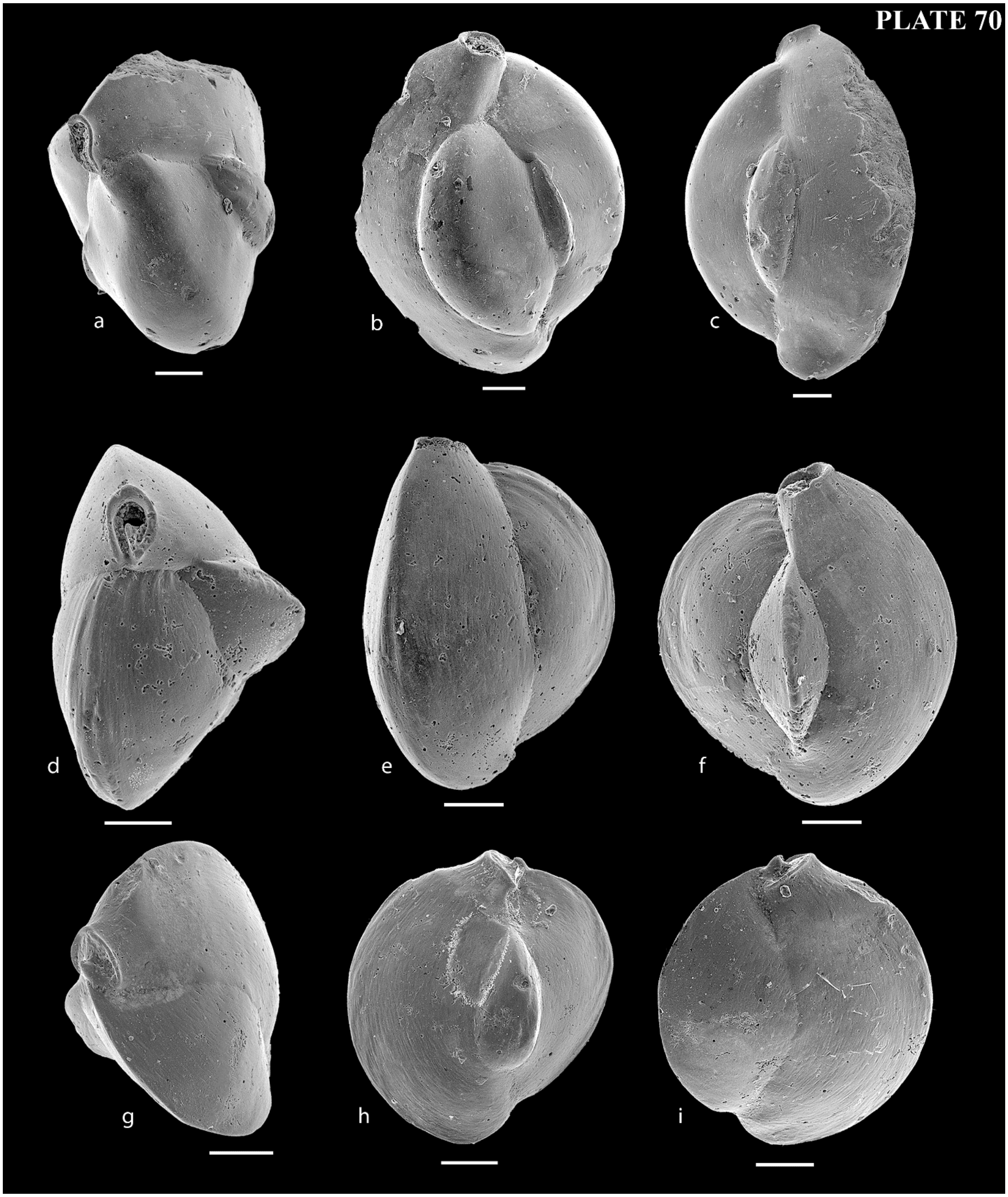
PLATE 70 (*Quinqueloculina* sp. 2 – *Quinqueloculina* sp. 6)

a–c ***Quinqueloculina* sp. 2** (a) apertural view (b) lateral view (c) lateral view of the opposite side.

d–f ***Quinqueloculina* sp. 7** (d) apertural view (e) lateral view (f) lateral view of the opposite side.

g–i ***Quinqueloculina* sp. 6** (g) apertural view (h) lateral view (i) lateral view of the opposite side.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CHAPTER 11

Conclusions

Several conculsions were presented in the preceding chapters, however the following points summarize the major findings from the study of benthic foraminiferal distribution, ecology and taxonomy in the Arabian Gulf

1. Significant higher diversity compared to any earlier study in the region is reported.
2. Documentation of foraminifera-foraminifera interaction in which the attachment of epibiotic individuals of one species influences the growth and morphology of several other species.
3. Documentation of the foraminiferal distribution gradient in shallow to deeper marine environments of the Gulf.
4. Discovery and naming of new species: *Pseudonubeculina arabica* and *Pseudotriloculina hottingeri*.
5. Documentation of foraminiferal distribution and taxonomy in over 60% of the area of the entire Gulf.
6. Ecological study of a hypersaline environment, Salwa Bay, Saudi Arabia
7. Documentation of foraminiferal assemblages in a relatively unimpacted environment of the Arabian Gulf, Murray's Pool in Bahrain, which has since been profoundly impacted.
8. Documentation of foraminifera in shallow paralic environments.
9. Distribution of autochthonous foraminiferal groups in open marine settings.
10. Atlas of Foraminifera in the Gulf.

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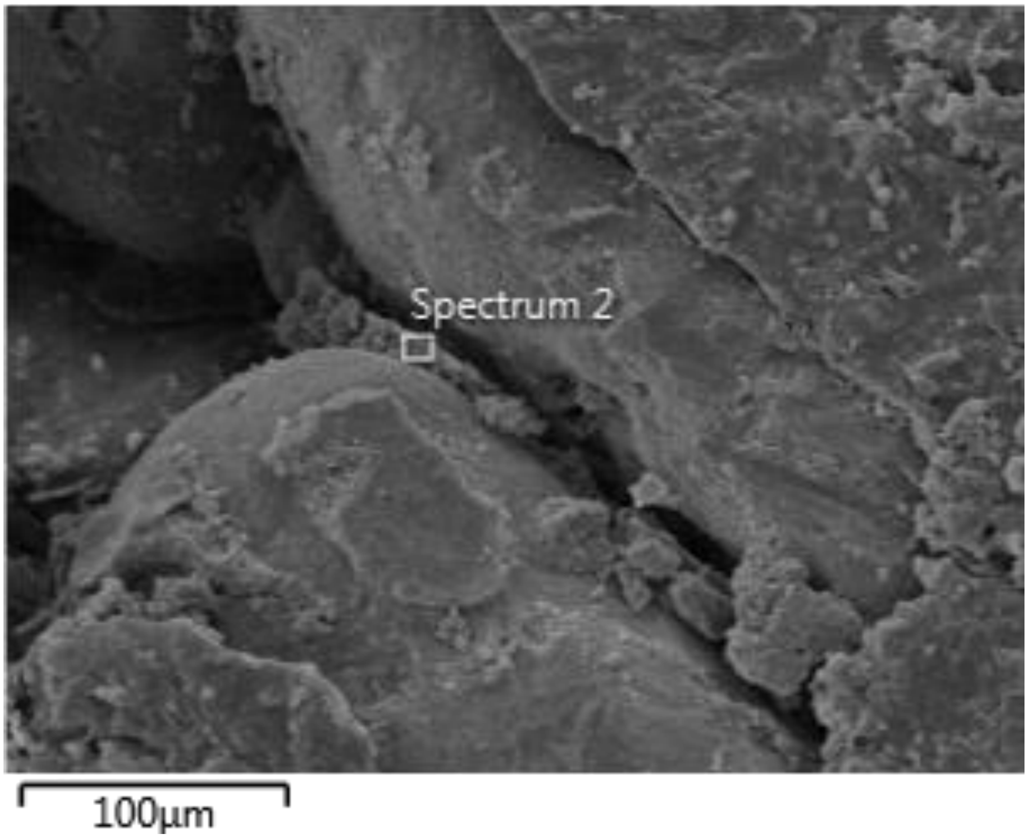
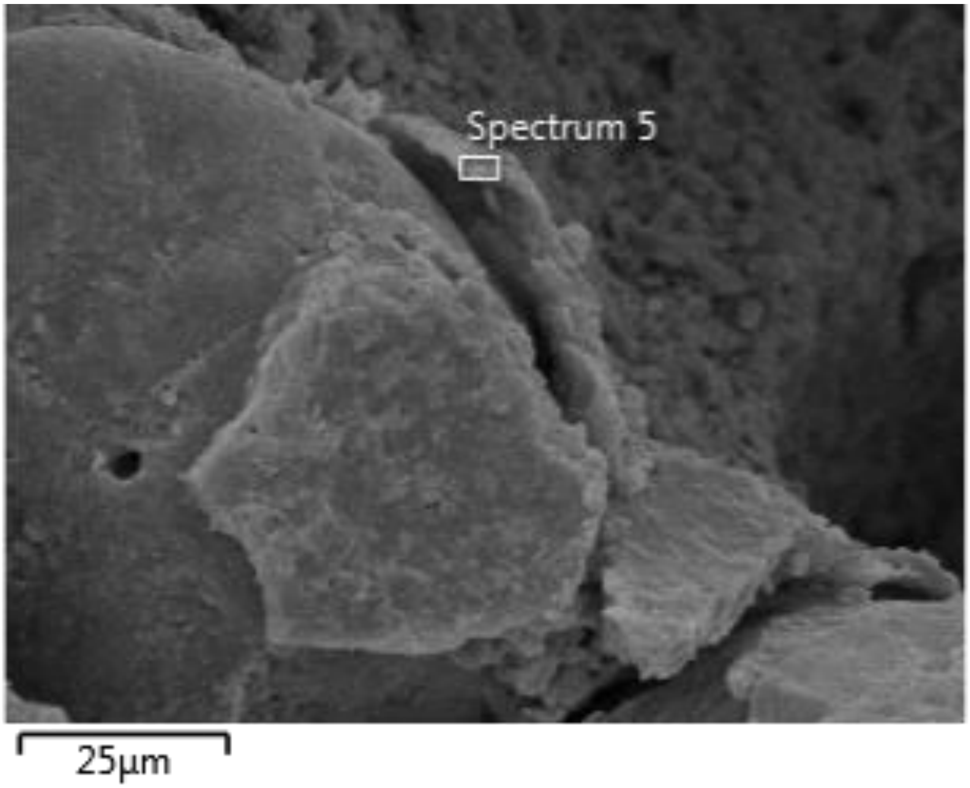
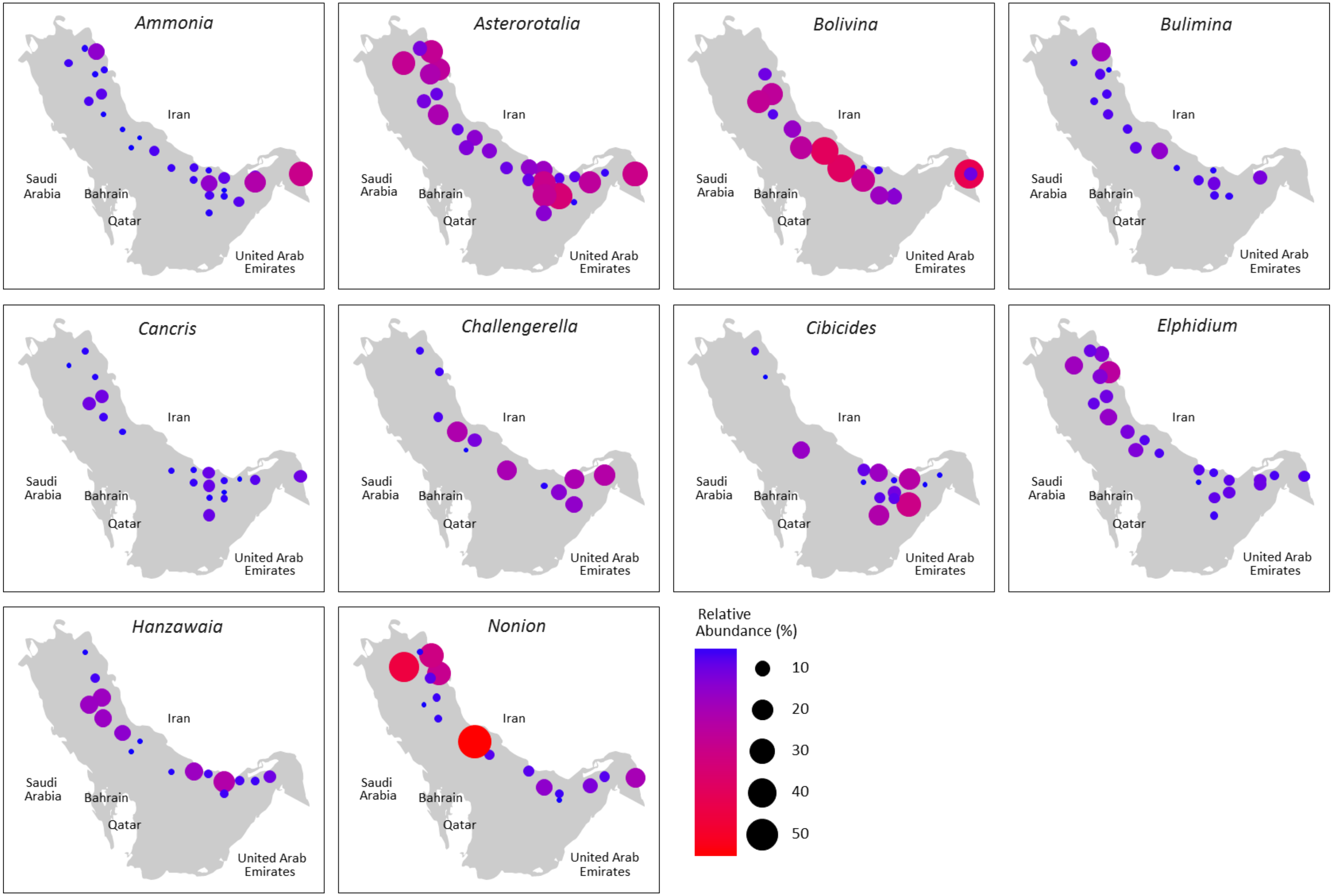
APPENDIX



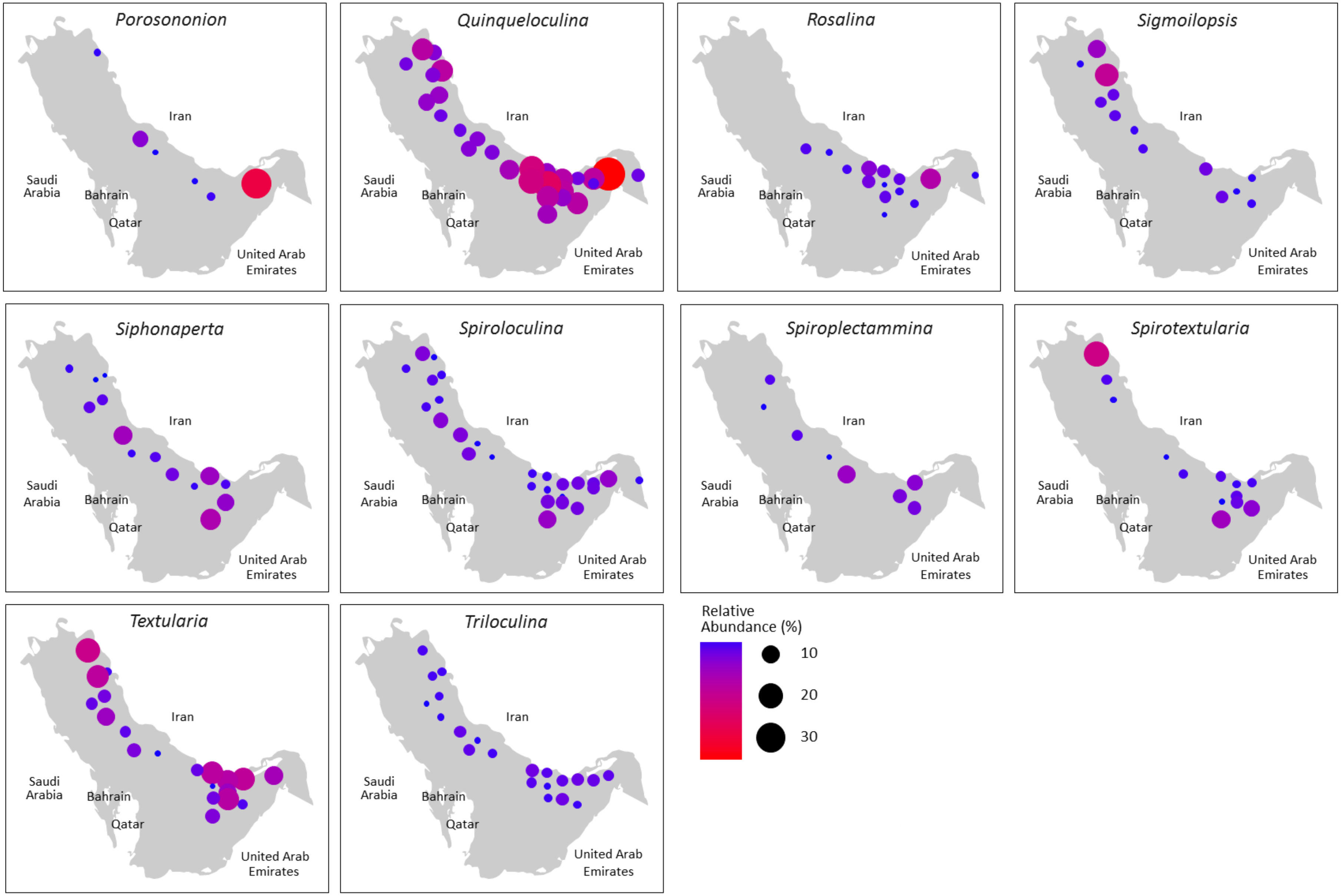
Appendix-Figure 1. EDX analysis spectrum 2



Appendix-Figure 2. EDX analysis spectrum 5



Appendix-Figure 3. Distribution map of the most abundant taxa recognized in the Gulf



Appendix-Figure 4. second group of ten out of the top 20 genera with the highest relative abundances arranged alphabetically and showing spatial distribution of groups from northeast to southeast.

Appendix-Table 1. Entire dataset used in the study and details of relative abundances for *P. hottingeri*

Stations	Latitude	Longitude	Depth (m)	Relative abundance (%)
S05F_01	28.3786787	49.1839712	42.00	0.00
S05F_02	28.3860191	49.2291915	42.50	0.00
S05F_03	28.3142594	49.5240289	49.30	0.00
S05F_04	28.3751298	49.6323919	47.00	0.00
S05F_05	28.3751298	49.5323919	48.00	0.00
S05F_06	28.1924708	49.0745016	23.00	0.00
S05F_07	28.5372517	49.4835590	44.60	0.00
S05F_08	28.5359648	49.3724005	43.90	0.00
S05F_09	28.4389130	49.4849638	44.80	0.00
S05F_10	27.6965762	49.0531496	8.70	4.10
S05F_11	27.6979524	49.1536030	9.20	4.20
S05F_12	27.6067703	49.0547400	5.70	2.30
S05F_13	27.9274847	49.7701284	46.20	0.00
S05F_14	27.9281711	49.8495480	57.80	0.00
S05F_15	28.1647342	49.9169867	41.90	0.00
S05F_16	28.2707583	49.9159163	51.60	0.00
S05F_17	28.0594647	49.9180438	19.10	0.00
S05F_18	27.5296130	49.6529177	19.90	0.00
S05F_19	27.5304297	49.7400203	22.10	0.00
S05F_20	27.7069914	50.0299622	54.20	0.00
S05F_21	27.7631245	50.0294650	52.50	0.00
S05F_22	27.7065330	49.9666091	57.60	0.00
S05F_23	27.1954508	49.7852114	23.40	0.00
S05F_24	27.2344377	49.7410607	17.10	2.40
S05F_25	27.4331159	50.0665901	60.20	0.00
S05F_26	27.4340760	50.2230472	57.20	0.00
S05F_27	27.4319678	49.9085463	40.20	0.00
S05F_28	26.9881304	50.5405060	37.40	0.00
S05F_29	26.9882380	50.5747779	35.90	0.00
S05F_30	26.9574453	50.5406305	37.80	0.00
S05F_31	24.7637910	50.7542240	0.40	1.20
S05F_32	24.7636080	50.7539650	0.60	1.20
S05F_33	24.7636080	50.7539650	0.60	2.90
S05F_34	24.7634670	50.7537410	0.76	1.50
S05F_35	24.7633440	50.7535210	0.87	1.30
S05F_36	24.7632110	50.7533070	0.98	3.30
S05F_37	24.7631110	50.7531140	1.09	1.50
S05F_38	24.7630100	50.7529260	1.20	1.80

S05F_39	24.7629100	50.7527280	1.31	1.30
S05F_40	24.7627990	50.7525010	1.53	0.00
S05F_41	24.7627080	50.7522750	1.64	0.80
S05F_42	26.4502700	55.5000000	21.00	0.00
S05F_43	28.5513900	50.4500000	21.00	0.00
S05F_44	25.9975500	54.0050300	20.00	0.00
S05F_45	27.1166700	52.1847200	21.00	0.00
S05F_46	26.6847200	52.7500000	24.00	0.00
S05F_47	26.2999900	53.9841600	23.00	0.00
S05F_48	29.1666700	50.5333300	22.00	0.00
S05F_49	26.3333300	55.5000000	23.00	0.00
S05F_50	26.5400000	56.9502800	23.00	0.00
S05F_51	29.6166700	50.2844500	19.00	0.00
S05F_52	26.5400000	57.0000000	19.00	0.00
S05F_53	27.4513900	51.7013900	22.00	0.00
S05F_54	29.3333400	49.3666600	16.00	0.00
S05F_55	26.4333300	54.4833300	18.00	0.00
S05F_56	26.6350000	53.9666600	28.00	0.00
S05F_57	28.0333400	50.5000000	21.00	0.00
S05F_58	26.1333300	54.4833300	24.00	0.00
S05F_59	26.4666700	54.9833300	31.00	0.00
S05F_60	27.2000000	51.4180600	25.00	0.00
S05F_61	29.7011100	49.9013900	21.00	0.00
S05F_62	27.6666600	51.1347300	20.00	0.00
S05F_63	26.7000000	53.4833300	21.00	0.00
S05F_64	28.3691400	50.0316600	20.00	0.00
S05F_65	25.5524800	53.9848500	21.00	0.00
S05F_66	26.3833400	53.4666700	21.00	0.00
S05F_67	25.8333300	54.9666600	22.00	0.00
S05F_68	29.0500000	50.2333300	23.00	0.00
S05F_69	25.9749900	54.4833300	24.00	0.00
S05F_70	26.5674900	55.9824400	21.20	0.00
S05F_71	26.5400000	56.0000000	21.00	0.00
S05F_72	26.0436170	50.6252210	0.02	2.17
S05F_73	26.0436690	50.6251410	0.40	0.77
S05F_74	26.0444720	50.6264440	1.00	3.64
S05F_75	26.0433190	50.6254720	0.10	0.00
S05F_76	26.0433740	50.6255230	0.02	2.49
S05F_77	26.0434030	50.6254990	0.04	0.60
S05F_78	26.0435130	50.6253670	0.40	4.49

Appendix-Table 2. Grains size analysis details for Salwa.

		1C	2C	3C	4C	5C	6C	7C	8C	9C	10C
	ANALYST AND DATE:	Amao, 02.10.2016	Amao, 02.10.2016	Amao, 02.10.2016	Amao, 02.10.2016	Amao, 02.10.2016	Amao, 02.10.2016	Amao, 02.10.2016	Amao, 02.10.2016	Amao, 02.10.2016	Amao, 02.10.2016
	SAMPLE TYPE:	Unimodal, Moderately Sorted	Unimodal, Moderately Sorted	Bimodal, Poorly Sorted	Bimodal, Moderately Sorted	Unimodal, Moderately Sorted	Unimodal, Moderately Sorted	Unimodal, Moderately Sorted	Bimodal, Moderately Sorted	Unimodal, Moderately Sorted	Unimodal, Moderately Sorted
	TEXTURAL GROUP:	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand
	SEDIMENT NAME:	Moderately Sorted Medium Sand	Moderately Sorted Medium Sand	Poorly Sorted Medium Sand	Moderately Sorted Medium Sand	Moderately Sorted Medium Sand	Moderately Sorted Medium Sand	Moderately Sorted Medium Sand	Moderately Sorted Medium Sand	Moderately Sorted Medium Sand	Moderately Sorted Medium Sand
METHOD OF	MEAN	411.5	431.9	357.2	397.5	468.1	432.8	482.0	452.1	437.5	423.3
MOMENTS	SORTING	193.5	215.6	271.5	267.4	250.5	235.0	236.1	263.0	241.5	228.4
Arithmetic (mm)	SKEWNESS	0.885	1.258	1.541	1.488	0.972	1.335	0.942	1.040	1.021	1.347
	KURTOSIS	4.289	5.321	4.995	4.806	3.748	4.889	3.926	4.000	4.010	5.238
METHOD OF	MEAN	364.4	372.0	266.7	312.1	392.3	366.3	414.7	360.9	365.1	357.1
MOMENTS	SORTING	1.660	1.956	2.430	2.340	2.067	2.025	1.965	2.374	2.034	2.055
Geometric (mm)	SKEWNESS	-0.521	-4.064	-2.297	-3.195	-3.587	-3.916	-4.078	-3.518	-3.037	-3.905
	KURTOSIS	3.085	36.23	16.59	23.45	29.84	34.17	36.54	24.36	25.51	32.82
METHOD OF	MEAN	1.456	1.369	1.807	1.571	1.287	1.381	1.214	1.361	1.403	1.414
MOMENTS	SORTING	0.731	0.722	1.009	0.880	0.799	0.744	0.729	0.880	0.830	0.757
Logarithmic (f)	SKEWNESS	0.521	0.385	-0.166	-0.152	0.396	0.057	0.437	0.448	0.368	0.214
	KURTOSIS	3.085	3.603	2.398	2.809	3.209	3.141	3.429	3.018	2.927	3.330
FOLK AND	MEAN	366.7	393.8	285.3	343.1	421.1	389.3	440.0	396.5	383.8	379.6
WARD METHOD	SORTING	1.664	1.638	2.090	1.883	1.740	1.683	1.652	1.879	1.799	1.692
(mm)	SKEWNESS	-0.196	-0.045	0.059	0.157	-0.005	0.077	-0.024	-0.089	-0.080	0.002
	KURTOSIS	1.095	1.332	0.997	1.145	1.102	1.171	1.122	1.293	1.101	1.251
FOLK AND	MEAN	1.447	1.345	1.809	1.543	1.248	1.361	1.185	1.334	1.382	1.397
WARD METHOD	SORTING	0.735	0.712	1.063	0.913	0.799	0.751	0.724	0.910	0.848	0.759
(f)	SKEWNESS	0.196	0.045	-0.059	-0.157	0.005	-0.077	0.024	0.089	0.080	-0.002

	KURTOSIS	1.095	1.332	0.997	1.145	1.102	1.171	1.122	1.293	1.101	1.251
FOLK AND	MEAN:	Medium Sand	Medium Sand	Medium Sand	Medium Sand	Medium Sand	Medium Sand	Medium Sand	Medium Sand	Medium Sand	Medium Sand
WARD METHOD	SORTING:	Moderately Sorted	Moderately Sorted	Poorly Sorted	Moderately Sorted	Moderately Sorted	Moderately Sorted	Moderately Sorted	Moderately Sorted	Moderately Sorted	Moderately Sorted
(Description)	SKEWNESS:	Fine Skewed	Symmetrical	Symmetrical	Coarse Skewed	Symmetrical	Symmetrical	Symmetrical	Symmetrical	Symmetrical	Symmetrical
	KURTOSIS:	Mesokurtic	Leptokurtic	Mesokurtic	Leptokurtic	Mesokurtic	Leptokurtic	Leptokurtic	Leptokurtic	Mesokurtic	Leptokurtic
	MODE 1 (mm):	458.2	385.3	324.0	324.0	385.3	385.3	385.3	385.3	385.3	385.3
	MODE 2 (mm):			916.4	916.4				136.3		
	MODE 3 (mm):										
	MODE 1 (f):	1.131	1.381	1.631	1.631	1.381	1.381	1.381	1.381	1.381	1.381
	MODE 2 (f):			0.131	0.131				2.881		
	MODE 3 (f):										
	D_{10} (mm):	175.8	205.2	114.8	161.1	203.3	205.6	229.1	157.0	169.8	192.8
	D_{50} (mm):	389.5	394.7	281.7	318.7	412.3	376.4	436.4	405.3	391.0	377.2
	D_{90} (mm):	661.0	720.8	812.1	856.4	843.8	787.2	823.6	865.8	789.7	749.8
	(D_{90} / D_{10}) (mm):	3.759	3.513	7.072	5.317	4.151	3.829	3.594	5.513	4.650	3.890
	(D_{90} - D_{10}) (mm):	485.1	515.6	697.2	695.3	640.5	581.6	594.5	708.7	619.8	557.0
	(D_{75} / D_{25}) (mm):	1.908	1.739	2.660	2.134	2.020	1.877	1.883	2.002	2.095	1.841
	(D_{75} - D_{25}) (mm):	245.8	221.8	279.5	257.0	303.9	246.2	283.9	287.9	294.0	234.6
	D_{10} (f):	0.597	0.472	0.300	0.224	0.245	0.345	0.280	0.208	0.341	0.415
	D_{50} (f):	1.360	1.341	1.828	1.650	1.278	1.410	1.196	1.303	1.355	1.407
	D_{90} (f):	2.508	2.285	3.122	2.634	2.299	2.282	2.126	2.671	2.558	2.375
	(D_{90} / D_{10}) (f):	4.198	4.838	10.40	11.78	9.382	6.612	7.594	12.84	7.508	5.717
	(D_{90} - D_{10}) (f):	1.910	1.813	2.822	2.411	2.054	1.937	1.846	2.463	2.217	1.960
	(D_{75} / D_{25}) (f):	1.978	1.851	2.218	2.043	2.384	1.983	2.261	2.255	2.285	1.916
	(D_{75} - D_{25}) (f):	0.932	0.798	1.411	1.094	1.015	0.908	0.913	1.001	1.067	0.881
	% GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	% SAND:	100.0%	100.0%	99.5%	99.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	% MUD:	0.0%	0.0%	0.5%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	% V COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	% COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	% MEDIUM GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	% FINE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

% V FINE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% V COARSE SAND:	1.0%	3.2%	5.6%	6.3%	4.9%	4.3%	4.3%	6.1%	3.7%	3.9%
% COARSE SAND:	26.4%	24.4%	15.3%	17.4%	30.9%	23.2%	34.0%	26.7%	28.2%	22.4%
% MEDIUM SAND:	51.5%	56.9%	35.9%	45.2%	48.1%	54.9%	49.5%	47.5%	46.7%	55.1%
% FINE SAND:	17.6%	12.4%	30.3%	26.6%	13.0%	15.3%	10.1%	13.8%	17.0%	15.4%
% V FINE SAND:	3.5%	3.0%	12.4%	4.4%	3.1%	2.2%	2.1%	5.8%	4.4%	3.1%
% V COARSE SILT:	0.0%	0.0%	0.5%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% COARSE SILT:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% MEDIUM SILT:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% FINE SILT:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% V FINE SILT:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% CLAY:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Appendix-Table 3. Relative abundance for Salwa samples (I)

Species	1A	R.A-1A	2A	R.A-2A	2C	R.A-2C	3A	R.A-3A	4A	R.A-4A	5A
Agglutinella robusta		0		0		0	1	0.2		0	
Adelosina sp.		0		0		0		0		0	
Agglutinella soriformis		0		0		0	2	0.4		0	
Clavulina angularis		0		0	2	0.4		0		0	
lachlanella sp		0	2	0.6	2	0.4	12	2.2	2	0.4	3
lachlanella corrugata	8	1.2	5	1.5	17	3.3	5	0.9	3	0.7	
Miliolinella cf M. circularis		0		0		0		0		0	
Miliolinella fusca		0		0		0		0		0	
Miliolinella sp. 1	8	1.2		0	9	1.7	32	5.8	2	0.4	5
Miliolinella sp. 2	2	0.3		0		0	2	0.4		0	1
Miliolinella sp. 3	5	0.7	7	2.1		0		0		0	1
Miliolinella sp. 4		0	3	0.9	11	2.1	25	4.5		0	
Pseudotriloculina sp. 1	8	1.2	4	1.2	15	2.9	8	1.5	6	1.3	11
Pseudotriloculina subgranulata		0	4	1.2	2	0.4	1	0.2	7	1.6	
Quinqueloculina quinquecarinata		0		0		0		0		0	
Quinqueloculina carinatastriata	7	1	5	1.5	3	0.6	18	3.3	2	0.4	3
Quinqueloculina seminulum	11	1.6	10	2.9	8	1.6	14	2.5	6	1.3	5
Quinqueloculina lamarckiana	4	0.6	3	0.9		0		0	4	0.9	
Quinqueloculina sp. 1	15	2.2	6	1.8	6	1.2	17	3.1	19	4.3	17
Quinqueloculina sp. 2	26	3.8	3	0.9	6	1.2	16	2.9	8	1.8	14
Quinqueloculina sp. 3	16	2.4	2	0.6		0	2	0.4	12	2.7	6
Quinqueloculina sp.4	16	2.4	3	0.9	19	3.7	18	3.3		0	
Quinqueloculina bicarinata	4	0.6		0		0		0		0	
Triloculina aff T. vespertilio		0		0		0		0		0	
Triloculina cf T. affinis		0		0		0		0		0	
Triloculina sp.		0		0		0		0		0	

Triloculina cf T. asymmentrica		0		0		0	5	0.9	1	0.2	3
Triloculina cf T. fichteliana sp. 1		0		0		0		0		0	
Ammonia convexa	37	5.5	9	2.6	18	3.5	21	3.8	43	9.6	30
Ammonia sp. 1	3	0.4	4	1.2	2	0.4	5	0.9	28	6.3	13
Ammonia sp. 2	7	1	1	0.3	3	0.6	6	1.1	6	1.3	11
Ammonia tepida	11	1.6	3	0.9	3	0.6	10	1.8	26	5.8	19
Elphidium craticulatum	6	0.9	2	0.6	4	0.8	12	2.2	39	8.7	20
Elphidium stratiopunctatum	5	0.7	3	0.9	2	0.4	8	1.5	9	2	7
Elphidium sp. 1	8	1.2	1	0.3	1	0.2	7	1.3	31	7	30
Elphidium fichtellianum		0	1	0.3	2	0.4	6	1.1		0	
Elphidium advenum	9	1.3	7	2.1	6	1.2	35	6.4	18	4	17
Elphidium gerthi	10	1.5	6	1.8	12	2.3	25	4.5	22	4.9	13
Coscinospira hemprichii	81	12	74	21.7	135	26.2	30	5.4	14	3.1	6
Coscinospira acicularis	24	3.6	2	0.6	6	1.2	13	2.4	2	0.4	2
Coscinospira arietina	32	4.7	14	4.1	30	5.8	29	5.3	3	0.7	4
Peneroplis pertasus	168	24.9	105	30.8	146	28.3	132	24	66	14.8	60
Peneroplis planatus	145	21.4	52	15.2	45	8.7	34	6.2	67	15	33
Rosalina sp.		0		0		0		0		0	

Appendix-Table 4. Relative abundance for Salwa samples (II).

Species	R.A-5A	6A	R.A-6A	7A	R.A-7A	8A	R.A-8A	9A	R.A-9A	10A	R.A-10A
Agglutinella robusta	0	1	0.5		0		0		0		0
Adelosina sp.	0	1	0.5		0		0		0		0
Agglutinella soriformis	0		0		0		0		0		0
Clavulina angularis	0		0		0		0		0		0
lachlanella sp	0.9	2	1		0		0		0		0
lachlanella corrugata	0		0		0		0		0		0
Miliolinella cf M. circularis	0		0		0		0		0		0
Miliolinella fusca	0		0		0		0		0		0
Miliolinella sp. 1	1.5		0	3	1.8	2	0.8		0		0
Miliolinella sp. 2	0.3	6	3.1	1	0.6	1	0.4	2	0.8		0
Miliolinella sp. 3	0.3		0		0		0		0		0
Miliolinella sp. 4	0	2	1	3	1.8	2	0.8	4	1.6		0
Pseudotriloculina sp. 1	3.3	3	1.5	3	1.8	3	1.3		0	1	0.8
Pseudotriloculina subgranulata	0		0		0	1	0.4		0		0
Quinqueloculina quinquecarinata	0	1	0.5		0		0		0		0
Quinqueloculina carinatastriata	0.9		0	2	1.2		0		0		0
Quinqueloculina seminulum	1.5	6	3.1	5	3		0		0		0
Quinqueloculina lamarckiana	0		0		0	4	1.7	1	0.4		0
Quinqueloculina sp. 1	5.1	18	9.3	14	8.3	6	2.5	4	1.6	10	8.3
Quinqueloculina sp. 2	4.2	2	1	5	3	9	3.8	5	2	4	3.3
Quinqueloculina sp. 3	1.8	11	5.7	5	3	4	1.7	6	2.3	3	2.5
Quinqueloculina sp.4	0	4	2.1	1	0.6	9	3.8	8	3.1		0
Quinqueloculina bicarinata	0		0		0		0		0		0
Triloculina aff T. vespertilio	0	1	0.5		0		0		0		0
Triloculina cf T. affinis	0		0		0		0		0		0
Triloculina sp.	0		0		0	2	0.8	1	0.4		0

Triloculina cf T. asymmentrica	0.9		0		0		0		0		0
Triloculina cf T. fichteliana sp. 1	0		0		0		0		0		0
Ammonia convexa	9	21	10.8	9	5.3	29	12.3	17	6.6	7	5.8
Ammonia sp. 1	3.9		0		0		0	2	0.8		0
Ammonia sp. 2	3.3		0	8	4.7		0	1	0.4		0
Ammonia tepida	5.7	9	4.6	3	1.8	5	2.1	14	5.5	4	3.3
Elphidium craticulatum	6	9	4.6	7	4.1	12	5.1	8	3.1		0
Elphidium stratiopunctatum	2.1	1	0.5		0	2	0.8		0		0
Elphidium sp. 1	9		0		0	5	2.1	11	4.3	8	6.6
Elphidium fichtellianum	0	1	0.5		0		0	1	0.4		0
Elphidium advenum	5.1	12	6.2	12	7.1	8	3.4	9	3.5		0
Elphidium gerthi	3.9	4	2.1	5	3	7	3	4	1.6		0
Coscinospira hemprichii	1.8	13	6.7	7	4.1	14	5.9	3	1.2		0
Coscinospira acicularis	0.6		0	2	1.2	3	1.3	6	2.3		0
Coscinospira arietina	1.2	4	2.1	7	4.1	3	1.3		0		0
Peneroplis pertasus	18	25	12.9	41	24.3	55	23.3	74	28.9	45	37.2
Peneroplis planatus	9.9	36	18.6	26	15.4	50	21.2	75	29.3	39	32.2
Rosalina sp.	0	1	0.5		0		0		0		0

Appendix-Table 5. Diversity Indices for Salwa Study.

	Taxa_S	Individuals	Dominance_D	Simpson_1-D	Shannon_H	Evenness_e^H/S	Brillouin	Menhinick	Margalef	Equitability_J	Fisher_alpha	Berger-Parker	Chao-1
1A	27	676	0.1337	0.8663	2.514	0.4578	2.434	1.038	3.99	0.7629	5.629	0.2485	27
2A	28	341	0.1713	0.8287	2.315	0.3617	2.184	1.516	4.63	0.6948	7.225	0.3079	28.6
2C	27	515	0.167	0.833	2.323	0.3781	2.23	1.19	4.164	0.7049	6.062	0.2835	27
3A	31	551	0.08743	0.9126	2.917	0.5962	2.806	1.321	4.753	0.8494	7.104	0.2396	31.25
4A	26	446	0.08294	0.9171	2.759	0.6074	2.649	1.231	4.098	0.847	6.021	0.1502	26
5A	25	334	0.0791	0.9209	2.812	0.6657	2.674	1.368	4.13	0.8736	6.256	0.1796	25.5
6A	25	194	0.09114	0.9089	2.69	0.5892	2.494	1.795	4.556	0.8357	7.637	0.1856	30.25
7A	21	169	0.1098	0.8902	2.591	0.6351	2.392	1.615	3.899	0.8509	6.32	0.2426	21.33
8A	23	236	0.1283	0.8717	2.482	0.5205	2.324	1.497	4.026	0.7917	6.303	0.2331	23.2
9A	21	256	0.1844	0.8156	2.189	0.4252	2.058	1.313	3.607	0.7191	5.417	0.293	23
10A	9	121	0.2596	0.7404	1.64	0.5728	1.525	0.8182	1.668	0.7464	2.248	0.3719	9

Appendix-Table 6. Details of deformed and normal test counts for Salwa study.

Genera	Station	Abudance	Living	Dead	Normal	Deformed	% Deformed	R. Abundance
Peneroplis	1A	313	99	214	134	179	57.2	47
Coscinospira	1A	137	54	83	66	71	51.8	20.6
Miliolinella	1A	15	1	14	10	5	33.3	2.3
Ammonia	1A	58	11	47	41	17	29.3	8.7
Elphidium	1A	38	4	34	32	6	15.8	5.7
Triloculina/Pseudotriloculina	1A	6	4	2	5	1	16.7	0.9
Quinqueloculina	1A	99	14	85	77	22	22.2	14.9
lachlanella	1A	8	1	7	7	1	12.5	1.2
Peneroplis	2A	157	57	100	42	115	73.2	46
Coscinospira	2A	90	11	79	30	60	66.7	26.4
Miliolinella	2A	10	3	7	3	7	70	2.9
Ammonia	2A	17	4	13	13	4	23.5	5
Elphidium	2A	20	5	15	18	2	10	5.9
Triloculina/Pseudotriloculina	2A	8	2	6	1	7	87.5	2.3
Quinqueloculina	2A	32	10	22	22	10	31.3	9.4
lachlanella	2A	7	2	5	6	1	14.3	2.1
Peneroplis	2C	191	91	100	77	114	59.7	37.2
Coscinospira	2C	171	45	126	89	82	48	33.3
Miliolinella	2C	22	7	15	12	10	45.5	4.3
Ammonia	2C	28	11	17	24	4	14.3	5.4
Elphidium	2C	31	6	25	20	11	35.5	6
Triloculina/Pseudotriloculina	2C	16	4	12	8	8	50	3.1
Quinqueloculina	2C	48	15	33	42	6	12.5	9.3
lachlanella	2C	7	2	5	6	1	14.3	1.4
Peneroplis	3A	166	64	102	54	112	67.5	30.3
Coscinospira	3A	72	24	48	46	26	36.1	13.2
Miliolinella	3A	59	9	50	52	7	11.9	10.8

Ammonia	3A	42	5	37	40	2	4.8	7.7
Elphidium	3A	93	10	83	13	80	86	17
Triloculina/Pseudotriloculina	3A	13	5	8	10	3	23.1	2.4
Quinqueloculina	3A	85	16	69	70	15	17.6	15.5
Lachlanella	3A	17	3	14	11	6	35.3	3.1
Peneroplis	4A	133	62	71	44	89	66.9	30
Coscinospira	4A	19	9	10	10	9	47.4	4.3
Miliolinella	4A	2	0	2	1	1	50	0.5
Ammonia	4A	103	28	75	91	12	11.7	23.2
Elphidium	4A	119	17	102	106	13	10.9	26.8
Triloculina/Pseudotriloculina	4A	14	4	10	5	9	64.3	3.2
Quinqueloculina	4A	49	13	36	36	13	26.5	11
Lachlanella	4A	5	0	5	1	4	80	1.1
Peneroplis	5A	93	27	66	38	55	59.1	27.8
Coscinospira	5A	12	3	9	9	3	25	3.6
Miliolinella	5A	7	3	4	5	2	28.6	2.1
Ammonia	5A	73	23	50	70	3	4.1	21.9
Elphidium	5A	87	14	73	78	9	10.3	26
Triloculina/Pseudotriloculina	5A	14	5	9	9	5	35.7	4.2
Quinqueloculina	5A	45	7	38	38	7	15.6	13.5
Lachlanella	5A	3	0	3	2	1	33.3	0.9
Peneroplis	6A	60	20	40	20	40	66.7	31.6
Coscinospira	6A	17	9	8	11	6	35.3	8.9
Miliolinella	6A	8	2	6	5	3	37.5	4.2
Ammonia	6A	29	4	25	28	1	3.4	15.3
Elphidium	6A	27	8	19	24	3	11.1	14.2
Triloculina/Pseudotriloculina	6A	4	0	4	3	1	25	2.1
Quinqueloculina	6A	43	8	35	36	7	16.3	22.6
Lachlanella	6A	2	0	2	1	1	50	1.1
Peneroplis	7A	67	5	62	19	48	71.6	40.1
Coscinospira	7A	16	4	12	9	7	43.8	9.6

Miliolinella	7A	7	1	6	3	4	57.1	4.2
Ammonia	7A	20	5	15	17	3	15	12
Elphidium	7A	24	4	20	22	2	8.3	14.4
Triloculina/Pseudotriloculina	7A	3	0	3	2	1	33.3	1.8
Quinqueloculina	7A	30	8	22	16	14	46.7	18
Lachlanella	7A	0	0	0	0	0	0	0
Peneroplis	8A	105	12	93	53	52	49.5	44.1
Coscinospira	8A	20	6	14	7	13	65	8.4
Miliolinella	8A	5	0	5	1	4	80	2.1
Ammonia	8A	34	7	27	33	1	2.9	14.3
Elphidium	8A	34	3	31	31	3	8.8	14.3
Triloculina/Pseudotriloculina	8A	6	0	6	5	1	16.7	2.5
Quinqueloculina	8A	33	8	25	25	8	24.2	13.9
Lachlanella	8A	1	0	1	1	0	0	0.4
Peneroplis	9A	149	31	118	52	97	65.1	57.8
Coscinospira	9A	9	2	7	4	5	55.6	3.5
Miliolinella	9A	4	1	3	3	1	25	1.6
Ammonia	9A	34	7	27	30	4	11.8	13.2
Elphidium	9A	33	3	30	27	6	18.2	12.8
Triloculina/Pseudotriloculina	9A	3	0	3	2	1	33.3	1.2
Quinqueloculina	9A	26	2	24	22	4	15.4	10.1
Lachlanella	9A	0	0	0	0	0	0	0
Peneroplis	10A	84	2	82	36	48	57.1	69.4
Coscinospira	10A	0	0	0	0	0	0	0
Miliolinella	10A	0	0	0	0	0	0	0
Ammonia	10A	11	2	9	9	2	18.2	9.1
Elphidium	10A	8	0	8	6	2	25	6.6
Triloculina/Pseudotriloculina	10A	1	0	0	0	1	0	0.8
Quinqueloculina	10A	17	1	16	15	2	11.8	14
Lachlanella	10A	0	0	0	0	0	0	0

Appendix-Table 7. Species list for Distribution of benthic foraminifera along the Iranian Coast.

Wall Type	Order	SuperFamily	Family	Genus	Species
hyaline	Rotaliida	Acervulinoidea	Acervulinoidae	*Acervulina*	*Acervulina cf. A. mahabeti*
hyaline	Rotaliida	Acervulinoidea	Acervulinoidae	*Acervulina*	*Acervulina sp. 01*
porcelaneous	Miliolida	Milioloidea	Cribrolinoididae	*Adelosina*	*Adelosina laevigata*
porcelaneous	Miliolida	Milioloidea	Cribrolinoididae	*Adelosina*	*Adelosina mediterranensis*
porcelaneous	Miliolida	Milioloidea	Cribrolinoididae	*Adelosina*	*Adelosina sp.01*
porcelaneous	Miliolida	Milioloidea	Cribrolinoididae	*Adelosina*	*Adelosina sp.02*
porcelaneous	Miliolida	Milioloidea	Cribrolinoididae	*Adelosina*	*Adelosina sp.03*
porcelaneous	Miliolida	Milioloidea	Cribrolinoididae	*Adelosina*	*Adelosina sp.04*
porcelaneous	Miliolida	Milioloidea	Cribrolinoididae	*Adelosina*	*Adelosina sp.05*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Ammonia*	*Ammonia cf. A. aberdoveyensis (1)*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Ammonia*	*Ammonia cf. A. faceta*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Ammonia*	*Ammonia cf. A. tepida*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Ammonia*	*Ammonia convexa 01*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Ammonia*	*Ammonia sp*
hyaline	Rotaliida	Asterigerinoidea	Amphisteginidae	*Amphistegina*	*Amphistegina lessonii*
hyaline	Rotaliida	Asterigerinoidea	Amphisteginidae	*Amphistegina*	*Amphistegina papillosa*
hyaline	Rotaliida	Nummulitoidea	Nummulitidae	*Assilina*	*Assilina sp*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Rotalinoides*	*Rotalinoides gaimardii (d'Orbigny, 1826)*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Asterorotalia*	*Asterorotalia dentata*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Asterorotalia*	*Asterorotalia sp.01*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Asterorotalia*	*Asterorotalia sp.02*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Asterorotalia*	*Asterorotalia sp.03*
hyaline	Rotaliida	Bolivinoidea	Bolivinidae	*Bolivina*	*Bolivina cf B. persiensis*
hyaline	Rotaliida	Bolivinoidea	Bolivinidae	*Bolivina*	*Bolivina cf. B. plicata*
hyaline	Rotaliida	Bolivinoidea	Bolivinidae	*Bolivina*	*Bolivina cf. B. striatula*
hyaline	Rotaliida	Bolivinoidea	Bolivinidae	*Bolivina*	*Bolivina cf. B.suezensis*
hyaline	Rotaliida	Bolivinoidea	Bolivinidae	*Bolivinellina*	*Bolivinellina cf. B. translucens*

hyaline	Rotaliida	Bolivinoidea	Bolivinidae	*Brizalina*	*Brizalina cf. B. subspathulata*
hyaline	Rotaliida	Bolivinoidea	Bolivinidae	*Brizalina*	*Brizalina sp. 01*
hyaline	Rotaliida	Bolivinoidea	Bolivinidae	*Brizalina*	*Brizalina striatula*
hyaline	Rotaliida	Buliminoidea	Buliminidae	*Bulimina*	*Bulimina biserialis*
hyaline	Rotaliida	Buliminoidea	Buliminidae	*Bulimina*	*Bulimina cf. B. marginata*
hyaline	Rotaliida	Buliminoidea	Buliminidae	*Bulimina*	*Bulimina marginata*
hyaline	Rotaliida	Buliminoidea	Buliminidae	*Bulimina*	*Bulimina sp. 01*
hyaline	Rotaliida	Buliminoidea	Buliminidae	*Bulimina*	*Bulimina sp. 02*
hyaline	Rotaliida	Buliminoidea	Buliminidae	*Bulimina*	*Bulimina sp. 03*
hyaline	Rotaliida	Buliminoidea	Buliminidae	*Bulimina*	*Bulimina sp. 04*
hyaline	Rotaliida	Discorboidea	Cancrisidae	*Cancris*	*Cancris bubnanensis*
hyaline	Rotaliida	Discorboidea	Cancrisidae	*Cancris*	*Cancris cf. C bubnanensis*
hyaline	Rotaliida	Discorboidea	Cancrisidae	*Cancris*	*Cancris cf. C oblongus*
hyaline	Rotaliida	Discorboidea	Cancrisidae	*Cancris*	*Cancris cf. C. auricularis*
hyaline	Rotaliida	Discorboidea	Cancrisidae	*Cancris*	*Cancris sp. 01*
hyaline	Rotaliida	Discorboidea	Cancrisidae	*Cancris*	*Cancris sp. 02*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Challengerella*	*Challengerella cf. C. persica*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Challengerella*	*Challengerella persica*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Challengerella*	*Challengerella sp. 01*
hyaline	Rotaliida	Planorbulinoidea	Cibicididae	*Cibicides*	*Cibicides sp. 01*
hyaline	Rotaliida	Planorbulinoidea	Cibicididae	*Cibicides*	*Cibicides cf. C. tabaensis*
hyaline	Rotaliida	Planorbulinoidea	Cibicididae	*Cibicides*	*Cibicides cf. C. phillipensis*
hyaline	Rotaliida	Planorbulinoidea	Cibicididae	*Cibicides*	*Cibicides cf. C. refulgens*
hyaline	Rotaliida	Planorbulinoidea	Cibicididae	*Lobatula*	*Lobatula lobatula (Walker & Jacob, 1798)*
hyaline	Rotaliida	Planorbulinoidea	Cibicididae	*Cibicides*	*Cibicides sp. 02*
hyaline	Rotaliida	Planorbulinoidea	Cymbaloporidae	*Cymbaloporetta*	*Cymbaloporetta sp. 01*
hyaline	Rotaliida	Planorbulinoidea	Cymbaloporidae	*Cymbaloporetta*	*Cymbaloporetta sp. 02*
hyaline	Rotaliida	Rotalioidea	Elphidiidae	*Elphidium*	*Elphidium advenum*
hyaline	Rotaliida	Rotalioidea	Elphidiidae	*Elphidium*	*Elphidium cf E. gerthi*
hyaline	Rotaliida	Rotalioidea	Elphidiidae	*Elphidium*	*Elphidium cf. advenum*
hyaline	Rotaliida	Rotalioidea	Elphidiidae	*Elphidium*	*Elphidium fichtellianum (d'Orbigny, 1846)*

hyaline	Rotaliida	Rotalioidea	Elphidiidae	*Elphidium*	*Elphidium cf. E. neosimplex*
hyaline	Rotaliida	Rotalioidea	Elphidiidae	*Elphidium*	*Elphidium craticulatum*
hyaline	Rotaliida	Rotalioidea	Elphidiidae	*Elphidium*	*Elphidium poeyanum*
hyaline	Rotaliida	Rotalioidea	Elphidiidae	*Elphidium*	*Elphidium sp.*
hyaline	Rotaliida	Discorboidea	Eponididae	*Eponides*	*Eponides sp*
agglutinated	Lituolida	Rzehakinoidea	Trilocularenidae	*Falsagglutinella*	*Falsagglutinella cf. F. angularis*
hyaline	Lagenida	Polymorphinoidea	Ellipsolagenidae	*Fissurina*	*Fissurina cf. F. bispinata*
hyaline	Lagenida	Polymorphinoidea	Ellipsolagenidae	*Fissurina*	*Fissurina lucida*
hyaline	Lagenida	Polymorphinoidea	Ellipsolagenidae	*Fissurina*	*Fissurina sp. 1*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Flintina*	*Flintina sp*
hyaline	Rotaliida	Fursenkoinoidea	Fursenkoinidae	*Fursenkoina*	*Fursenkoina sp 01*
hyaline	Rotaliida	Fursenkoinoidea	Fursenkoinidae	*Fursenkoina*	*Fursenkoina sp 02*
agglutinated	Lituolida	Verneuilinoidea	Verneuilinidae	*Gaudryina*	*Gaudryina attenuata*
agglutinated	Lituolida	Verneuilinoidea	Verneuilinidae	*Gaudryina*	*Gaudryina convexa*
agglutinated	Lituolida	Verneuilinoidea	Verneuilinidae	*Gaudryina*	*Gaudryina sp. 01*
agglutinated	Lituolida	Verneuilinoidea	Verneuilinidae	*Gaudryina*	*Gaudryina sp. 02*
agglutinated	Lituolida	Verneuilinoidea	Verneuilinidae	*Gaudryina*	*Gaudryina sp. 03*
hyaline	Rotaliida	Discorboidea	Discorbidae	*Gavelinopsis*	*Gavelinopsis cf. G. praegeri*
hyaline	Lagenida	Polymorphinoidea	Glandulinidae	*Glandulina*	*Glandulina cf. G. laevigata*
hyaline	Lagenida	Polymorphinoidea	Glandulinidae	*Glandulina*	*Glandulina laevigata*
hyaline	Lagenida	Polymorphinoidea	Glandulinidae	*Glandulina*	*Glandulina sp. 01*
hyaline	Lagenida	Polymorphinoidea	Glandulinidae	*Glandulina*	*Glandulina sp. 02*
hyaline	Lagenida	Polymorphinoidea	Glandulinidae	*Glandulina*	*Glandulina suezensis*
hyaline	Rotaliida	Acervulinoidea	Acervulinidae	*Gypsina*	*Gypsina sp. 01*
hyaline	Rotaliida	Chilostomelloidea	Anomalinidae	*Hanzawaia*	*Hanzawaia sp. 01*
hyaline	Rotaliida	Chilostomelloidea	Anomalinidae	*Hanzawaia*	*Hanzawaia sp. 02*
hyaline	Rotaliida	Chilostomelloidea	Anomalinidae	*Hanzawaia*	*Hanzawaia sp. 03*
agglutinated	Lituolida	Lituoloidea	Haplophragmoididae	*Haplophragmoides*	*Haplophragmoides pusillus*
hyaline	Lagenida	Nodosarioidea	Lagenidae	*Lagena*	*Lagena cf. L. semistriata*
hyaline	Lagenida	Nodosarioidea	Lagenidae	*Lagena*	*Lagena cf. L. strumosa*
hyaline	Lagenida	Nodosarioidea	Lagenidae	*Lagena*	*Lagena semistriata*

hyaline	Lagenida	Nodosarioidea	Lagenidae	*Lagena*	*Lagena strumosa*
agglutinated	Astrorhizida	Saccamminoidea	Saccamminidae	*Lagenammina*	*Lagenammina sp*
hyaline	Rotaliida	Polymorphinoidea	Cibicididae	*Lobatula*	*Lobatula lobatula*
hyaline	Rotaliida	Bolivinitoidea	Bolivinitoidae	*Loxostomina*	*Loxostomina costulata*
hyaline	Rotaliida	Bolivinitoidea	Bolivinitoidae	*Loxostomina*	*Loxostomina sp. 01*
hyaline	Rotaliida	Bolivinitoidea	Bolivinitoidae	*Loxostomina*	*Loxostomina sp. 02*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Miliolinella*	*Miliolinella chukchiensis*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Miliolinella*	*Miliolinella sp 01*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Miliolinella*	*Miliolinella sp 02*
				Neogallitelia	*Neogallitelia cf N. vivans*
hyaline	Rotaliida	Buliminoidea	Uvigerinidae	*Siphouvigerina*	*Siphouvigerina proboscidea (Schwager, 1866)*
hyaline	Rotaliida	Nonionoidea	Nonionidae	*Nonion*	*Nonion cf. N. depressulus*
hyaline	Rotaliida	Nonionoidea	Nonionidae	*Nonion*	*Nonion sp. 01*
hyaline	Rotaliida	Nonionoidea	Nonionidae	*Nonion*	*Nonion sp. 02*
porcelaneous	Miliolida	Nubecularioidea	Nubeculariidae	*Nubeculina*	*Nubeculina sp. 01*
hyaline	Rotaliida	Nonionoidea	Nonionidae	*Nonionella*	*Nonionella cf. N. iridea*
hyaline	Rotaliida	Nonionoidea	Nonionidae	*Nonionellina*	*Nonionellina cf. N. labradorica*
hyaline	Lagenida	Polymorphinoidea	Ellipsolagenidae	*Oolina*	*Oolina sp*
hyaline	Rotaliida	Rotalioidea	Elphidiidae	*Elphidium*	*Elphidium hispidulum Cushman, 1936*
hyaline	Rotaliida	Planorbulinidea	Planorbulinidae	*Planorbulina*	*Planorbulina sp*
hyaline	Rotaliida	Rotalioidea	Elphidiidae	*Cribroelphidium*	*Porosononion sp. 01*
hyaline	Rotaliida	Nonionoidea	Nonionidae	*Porosononion*	*Porosononion sp. 02*
				Praebulimina	*Praebulimina sp*
hyaline	Rotaliida	Rotalioidea	Rotaliidae	*Ammonia*	*Ammonia falsobeccarii (Rouvillois, 1974)*
hyaline	Rotaliida	Nonionoidea	Nonionidae	*Pseudononion*	*Pseudononion japonicum*
porcelaneous	Miliolida	Nubecularioidea	Nubeculariidae	*Pseudonubeculina*	*Pseudonubeculina sp. 01*
hyaline	Lagenida	Polymorphinoidea	Ellipsolagenidae	*Pygmaeoseistron*	*Pygmaeoseistron sp. 01*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Pyrgo*	*Pyrgo phlegeri*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Pyrgo*	*Pyrgo sarsi*
hyaline	Lagenida	Nodosarioidea	Nodosariidae	*Pyramidulina*	*Pyramidulina catesbyi*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina akneriana*

porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina bosciana*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina erinacea*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina cf. Q. myagmarsuren*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina cf. Q. quinquecarinata 03*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina cf. Q. subcuneata*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina crassicarinata*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Pseudotriloculina*	*Pseudotriloculina granulocostata (Germeraad, 1946)*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina limbata*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina poeyana*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 01*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 02*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 03*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 04*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 05*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 06*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 07*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 08*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 09*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 10*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 11*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 12*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 13*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 14*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 15*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 16*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 17*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 18*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 19*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 20*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina sp. 21*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina stalkeri*

hyaline	Rotaliida	Buliminoidea	Uvigerinidae	*Reussella*	*Reussella sp. 01*
hyaline	Rotaliida	Discorboidea	Rosalinidae	*Rosalina*	*Rosalina bradyi*
hyaline	Rotaliida	Discorboidea	Rosalinidae	*Rosalina*	*Rosalina sp. 01*
hyaline	Rotaliida	Discorboidea	Rosalinidae	*Rosalina*	*Rosalina sp. 02*
hyaline	Rotaliida	Discorboidea	Rosalinidae	*Rosalina*	*Rosalina sp. 03*
hyaline	Rotaliida	Discorboidea	Rosalinidae	*Rosalina*	*Rosalina sp. 04*
hyaline	Rotaliida	Bolivinitoidea	Bolivinitidae	*Sagrinella*	*Sagrinella lobata lobata*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Sahulia*	*Sahulia barkeri*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Sahulia*	*Sahulia cf. S barkeri*
hyaline	Rotaliida	Bolivinitoidea	Fursenkoinidae	*Sigmavirgulina*	*Sigmavirgulina sp. 01*
hyaline	Rotaliida	Bolivinitoidea	Fursenkoinidae	*Sigmavirgulina*	*Sigmavirgulina sp. 02*
hyaline	Rotaliida	Bolivinitoidea	Fursenkoinidae	*Sigmavirgulina*	*Sigmavirgulina sp. 03*
hyaline	Rotaliida	Bolivinitoidea	Fursenkoinidae	*Sigmavirgulina*	*Sigmavirgulina sp. 04*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Sigmoilopsis*	*Sigmoilopsis cf. S. herzensteini*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Sigmoilopsis*	*Sigmoilopsis sp. 01*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Sigmoilopsis*	*Sigmoilopsis sp. 02*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Sigmoilopsis*	*Sigmoilopsis sp. 03*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Sigmoilopsis*	*Sigmoilopsis sp. 04*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Sigmamiliolinella*	*Sigmamiliolinella australis (Parr 1932)*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Siphonaperta*	*Siphonaperta agglutinans*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Siphonaperta*	*Siphonaperta pittensis*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Siphonaperta*	*Siphonaperta sp. 01*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Siphonaperta*	*Siphonaperta sp. 02*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina aff. S. communis*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina cf. S. depressa*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina elegantissima*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina regularis*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina rotundata*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina sp. 01*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina sp. 02*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina sp. 03*

porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina sp. 04*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina sp. 05*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina sp. 06*
porcelaneous	Miliolida	Milioloidea	Spiroloculinidae	*Spiroloculina*	*Spiroloculina subimpressa*
agglutinated	Lituolida	Spiroplectamminoidea	Spiroplectamminidae	*Spiroplectammina*	*Spiroplectammina earlandi*
agglutinated	Lituolida	Spiroplectamminoidea	Spiroplectamminidae	*Spiroplectinella*	*Spiroplectinella sagittula*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Spirotextularia*	*Spirotextularia cf S. floridana*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia bocki*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia cf. T. foliacea*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia cf. T. foliacea occidentalis*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia cf.T. stricta*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia conica*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia cushmani*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia foliacea oceanica*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia foliacea*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia goessi*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia kerimbaensis*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia pala*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 01*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 02*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 03*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 04*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 05*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 06*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 07*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 08*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 09*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 10*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 11*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 12*
agglutinated	Textulariida	Textularioidea	Textulariidae	*Textularia*	*Textularia sp. 13*

porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina cf. T. tricarinata*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina elongotricarinata*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina fichteliana*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina sp.01*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina sp.02*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina sp.03*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina sp.04*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina terquemiana*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina tricarinata*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina trigonula*
porcelaneous	Miliolida	Milioloidea	Hauerinidae	*Triloculina*	*Triloculina wiesneri*
hyaline	Rotaliida	Buliminoidea	Trimosinidae	*Trimosina*	*Trimosina cf T. milletti multispinata*
hyaline	Rotaliida	Buliminoidea	Uvigerinidae	*Uvigerina*	*Uvigerina cf. U peregrina*

Appendix-Table 8. Relative abundance as a function of genera for Distribution of benthic foraminifera along the Iranian coast (I)

Labels	**T a 1**	**T a-3**	**T a-4**	**T 1-1**	**T 1-2**	**T 2-1**	**T 2-3**	**T 3-3**	**T 4-1**	**T 4-2**	**T 4-3**	**T 5-1**	**T 5-2**	**T 5-4**	**T 6-1**	**T 6-2**	**T 6-4**
S/N	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0
Acervulina	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Adelosina	0.0	0.0	0.0	0.0	0.0	0.5	0.0	5.1	0.4	0.5	0.9	1.8	0.0	0.5	0.0	0.4	0.5
Ammonia	4.2	27.1	1.8	39.3	13.3	0.0	8.0	0.0	19.7	3.9	4.8	0.4	1.0	0.9	12.2	2.8	1.1
Amphisterigina	2.1	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	7.4	0.0	0.0	0.0	0.4	0.5
Asterorotalia	17.2	27.6	26.8	5.5	1.4	1.6	2.0	4.3	23.1	1.0	4.0	10.9	32.3	14.3	27.0	25.0	10.5
Bolivina	0.0	6.5	41.1	0.0	41.9	0.0	0.0	0.0	0.0	0.0	0.0	0.4	10.6	1.8	0.0	14.5	0.0
Bolivinellina	0.0	0.0	0.9	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	3.6	2.0	0.0
Brizalina	0.4	11.2	1.8	0.0	3.3	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
Bulimina	0.0	0.0	0.0	0.0	1.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	1.5	0.9	6.6	2.4	0.0
Cancris	0.0	6.5	4.5	0.0	5.2	0.0	4.0	0.4	0.0	0.0	1.3	0.4	1.5	5.5	5.6	0.8	5.8
Challengerella	0.4	0.0	0.0	0.0	0.5	20.3	0.0	18.0	0.0	12.1	0.0	10.6	0.0	0.0	1.0	0.0	0.0
Cibicides	0.8	0.0	0.0	0.0	0.0	0.5	0.0	21.1	0.4	28.0	0.9	7.4	4.5	14.3	0.0	4.4	19.5
Cibicidoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0
Cymbaloporetta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	2.1
Elphidium	0.8	2.9	4.5	2.7	6.7	2.7	6.0	0.0	6.1	0.0	4.4	5.3	0.0	2.3	0.0	4.8	2.1
Eponides	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Falsagglutinella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Fissurina	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
Flintina	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fursenkoina	0.0	0.0	0.0	0.0	0.5	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0
Gaudryina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	1.9	1.8	0.7	0.0	0.5	0.0	0.4	0.0
Gavelinopsis	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glandulina	0.0	0.0	0.9	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Gypsina	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hanzawaia	0.4	0.0	0.0	0.0	0.0	6.6	2.0	2.7	0.0	0.0	19.8	2.1	0.0	2.3	0.0	0.0	0.0
Haplophragmoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Lagena	0.0	0.0	0.0	0.5	0.5	0.0	4.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.0	0.0	0.0
Lagenammina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Lobatula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	6.3	1.3	6.0	0.0	1.8	0.0	0.0	2.1
Loxostomina	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Miliolinella	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.0	0.0	1.8	0.0	0.0	0.0
Nonion	0.8	17.1	10.7	44.8	4.3	3.8	0.0	0.0	8.7	0.0	0.0	2.1	0.5	0.0	11.7	0.0	0.0
Nonionella	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nonionellina	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Nubeculina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2
Oolina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parrellina	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.4	0.0	0.0	0.0	4.6	0.0	0.0	0.0	0.0	0.0
Planorbulina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Porosononion	0.0	0.0	0.0	2.2	0.0	0.0	6.0	0.0	31.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0
Praebulimina	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudoeponides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Pseudononion	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudonubeculina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	1.9	0.0	2.1	0.5	0.0	0.0	1.2	0.0
Pygro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyramidulina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.5	0.0	0.0
Quinqueloculina	56.1	0.0	4.5	1.6	4.8	38.5	16.0	5.1	3.1	15.0	14.5	15.8	9.1	9.2	26.0	15.3	11.1
Reussella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rosalina	0.0	0.0	0.9	0.0	4.3	0.0	14.0	0.0	0.0	1.4	3.5	1.4	0.0	5.1	0.5	3.6	0.5
Sagrinella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sahulia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	1.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0
Sigmavirgulina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.4	0.0	0.0	0.0	0.0	2.0	1.1
Sigmoilopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	1.4	0.0	0.7	0.0	0.0	0.0	4.0	0.0
Sigmomiliolinella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
Siphonaperta	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	2.2	0.0	8.6	10.1	0.0	0.0	13.2
Spiroloculina	7.9	1.2	0.0	1.6	1.4	8.8	4.0	4.7	4.4	4.8	4.4	0.4	5.1	1.8	1.0	5.2	9.5
Spiroplectammina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.4	0.0	5.3	0.0	5.6	0.0	0.0	0.0	0.0	0.0
Spiroplectinella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Spirotextularia	2.1	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	7.7	1.3	3.2	4.0	2.8	0.0	0.4	10.5
Textularia	0.4	0.0	0.0	0.0	4.3	11.5	0.0	16.8	0.0	2.4	14.5	9.9	15.2	15.7	0.5	4.8	6.3
Triloculina	0.0	0.0	0.0	0.0	0.0	3.3	4.0	4.3	0.0	1.4	3.5	0.0	4.5	2.8	1.0	1.6	0.0
Trimosina	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uvigerina	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0

Appendix-Table 9. Relative abundance as a function of genera for Distribution of benthic foraminifera along the Iranian Coast (II).

Labels	T 7-1	T 7-2	T 8-2	T 9-2	T 10-2	T 10-3	T 11-2	T 12-3	T 13-2	T 13-3	T 14-1	T 14-2	T 15-1	T 16-1	T 16-4
S/N	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0
Acervulina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adelosina	1.6	0.0	0.0	0.0	0.3	0.0	0.0	4.3	1.7	0.5	0.9	0.3	0.0	0.0	3.0
Ammonia	2.4	1.7	1.9	3.1	0.3	0.4	0.5	0.5	4.4	2.9	1.2	0.6	11.6	2.1	0.9
Amphisterigina	1.6	13.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Asterorotalia	11.9	5.6	5.8	9.6	11.0	9.0	5.2	18.1	5.7	7.7	23.3	18.6	24.9	25.3	8.2
Bolivina	0.8	26.0	36.9	38.2	0.0	22.7	13.2	3.7	23.6	24.6	0.0	6.6	0.0	0.0	0.0
Bolivinellina	0.0	6.8	2.9	3.9	0.0	0.0	1.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Brizalina	0.0	0.6	1.9	0.9	5.6	0.4	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bulimina	0.0	3.4	1.0	11.8	0.0	4.7	2.8	3.7	2.7	1.9	0.6	3.8	15.9	1.3	0.0
Cancris	0.8	1.7	1.0	0.0	0.0	0.0	0.9	2.1	6.7	6.8	0.0	0.9	0.0	0.4	1.2
Challengerella	0.0	0.0	17.5	0.0	7.9	0.4	18.9	3.2	0.0	0.0	2.3	0.0	0.0	0.0	1.8
Cibicides	5.6	0.6	0.0	0.0	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	2.1
Cibicidoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Cymbaloporetta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elphidium	4.0	0.6	0.0	3.1	3.6	9.0	8.0	12.8	6.7	5.3	22.4	9.7	10.1	15.0	6.1
Eponides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Falsagglutinella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fissurina	0.0	0.6	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.5	0.3	0.0	0.0	0.4	0.0
Flintina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fursenkoina	0.0	0.6	0.0	1.3	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Gaudryina	0.0	0.0	0.0	0.4	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gavelinopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glandulina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.7	0.0
Gypsina	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hanzawaia	14.3	0.0	1.0	0.0	0.5	0.4	11.3	13.8	14.5	14.0	0.0	2.5	0.0	0.0	0.6

Haplophragmoides	0.0	0.6	0.0	0.4	0.0	0.0	0.0	0.0	0.3	0.5	0.6	0.0	0.0	0.0	0.0
Lagena	0.0	0.6	0.0	0.9	0.0	0.0	0.0	0.5	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Lagenammina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lobatula	0.0	1.1	0.0	2.2	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Loxostomina	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0
Miliolinella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	1.0	0.9	0.6	0.0	0.0	0.0
Nonion	4.0	0.0	0.0	3.9	54.6	0.0	0.0	1.6	2.0	0.5	26.2	4.4	29.1	44.6	0.9
Nonionella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nonionellina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Nubeculina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oolina	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parrellina	0.0	0.0	0.0	0.0	0.3	0.0	0.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planorbulina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Porosononion	0.0	0.6	0.0	0.4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0
Praebulimina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudoeponides	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudononion	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	3.4	0.0	0.0	0.0	0.0	0.0
Pseudonubeculina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pygro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.3	0.0	0.0	0.0
Pyramidulina	0.0	0.0	0.0	0.9	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quinqueloculina	21.4	20.9	11.7	6.1	6.9	6.9	4.2	4.3	9.4	8.7	15.5	6.6	6.9	5.2	15.2
Reussella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Rosalina	7.1	5.1	1.9	0.9	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sagrinella	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sahulia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	1.8
Sigmavirgulina	3.2	1.7	0.0	0.0	0.0	0.0	0.5	2.1	2.7	3.9	0.3	0.6	0.0	0.0	0.0
Sigmoilopsis	4.8	0.0	0.0	0.0	0.0	2.1	1.4	3.2	3.7	3.4	0.0	17.3	0.0	0.9	10.0
Sigmomiliolinella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Siphonaperta	0.0	1.1	4.9	2.6	0.0	1.3	10.8	0.0	3.0	3.4	0.3	0.3	0.0	1.3	0.0
Spiroloculina	1.6	1.7	0.0	0.4	0.5	5.2	6.1	6.9	1.3	1.9	1.5	3.1	0.5	1.7	6.4

Spiroplectammina	0.0	0.0	9.7	0.4	0.0	0.0	2.8	0.0	0.0	0.5	0.0	2.5	0.0	0.0	0.0
Spiroplectinella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spirotextularia	0.0	0.0	1.9	0.4	0.0	0.0	0.0	0.0	0.7	0.0	0.0	2.5	0.0	0.0	20.0
Textularia	4.0	0.0	0.0	0.4	0.0	6.0	3.3	10.1	5.1	3.9	1.7	16.0	0.0	0.0	19.1
Triloculina	4.8	2.8	0.0	1.8	0.8	3.4	3.8	1.1	1.7	0.5	1.7	1.9	0.0	0.0	2.1
Trimosina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Uvigerina	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix-Table 10. Diversity Indices for Distribution of benthic foraminifera along the Iranian Coast (I).

Labels	Latitude	Longitude	Depth	Clusters	Individuals	Dominance_D	Simpson_1-D	Shannon_H
T 2-3	26.45027	55.5	21	Cluster_1	50	0.0592	0.9408	3.012
T 13-2	28.55139	50.45	21	Cluster_1	297	0.09696	0.903	2.848
T 6-2	25.99755	54.00503	20	Cluster_1	248	0.1065	0.8935	2.763
T 9-2	27.11667	52.18472	21	Cluster_1	228	0.1811	0.8189	2.387
T 8-2	26.68472	52.75	24	Cluster_1	103	0.1694	0.8306	2.311
T 1-2	NA	NA	NA	Cluster_1	210	0.2037	0.7963	2.197
T 6-1	26.29999	53.98416	23	Cluster_1	196	0.1667	0.8333	2.161
T 14-1	29.16667	50.53333	22	Cluster_1	343	0.1799	0.8201	2.14
T 4-1	26.33333	55.5	23	Cluster_1	229	0.1904	0.8096	2.031
T a-4	26.54	56.95028	NA	Cluster_1	112	0.2369	0.7631	1.902
T 15-1	29.61667	50.28445	19	Cluster_2	189	0.1954	0.8046	1.806
T a-3	26.54	57	NA	Cluster_1	170	0.1974	0.8026	1.795
T 10-2	27.45139	51.70139	22	Cluster_1	390	0.3211	0.6789	1.788
T 16-1	29.33334	49.36666	16	Cluster_1	233	0.281	0.719	1.72
T 1-1	NA	NA	20	Cluster_1	183	0.3557	0.6443	1.381
T 4-3	26.43333	54.48333	18	Cluster_2	227	0.06981	0.9302	3.261
T 5-4	26.635	53.96666	28	Cluster_2	217	0.07821	0.9218	2.971
T 12-3	28.03334	50.5	21	Cluster_2	188	0.07588	0.9241	2.968
T 5-1	26.13333	54.48333	24	Cluster_2	284	0.0764	0.9236	2.924
T 3-3	26.46667	54.98333	31	Cluster_2	256	0.09778	0.9022	2.914
T 10-3	27.2	51.41806	25	Cluster_2	233	0.09182	0.9082	2.828
T 16-4	29.70111	49.90139	21	Cluster_2	330	0.08162	0.9184	2.82
T 11-2	27.66666	51.13473	20	Cluster_2	212	0.07427	0.9257	2.81
T 7-1	26.7	53.48333	21	Cluster_2	126	0.09196	0.908	2.79
T 13-3	28.36914	50.03166	20	Cluster_2	207	0.09991	0.9001	2.764
T 6-4	25.55248	53.98485	21	Cluster_2	190	0.09668	0.9033	2.682

T 7-2	26.38334	53.46667	21	Cluster_2	177	0.1268	0.8732	2.68
T 4-2	25.83333	54.96666	22	Cluster_2	207	0.1265	0.8735	2.643
T 14-2	29.05	50.23333	23	Cluster_2	318	0.1053	0.8947	2.626
T 5-2	25.97499	54.48333	24	Cluster_2	198	0.1526	0.8474	2.336
T 2-1	26.56749	55.98244	21.2	Cluster_2	182	0.1867	0.8133	2.18
T a 1	26.54	56	NA	Cluster_2	239	0.3202	0.6798	1.844

Appendix-Table 11. Diversity Indices for Distribution of benthic foraminifera along the Iranian Coast (II).

Labels	Evenness_e^H/S	Brillouin	Menhinick	Margalef	Equitability_J	Fisher_alpha	Berger-Parker	Chao-1
T 2-3	0.8134	2.458	3.536	6.135	0.9359	19.9	0.12	47.75
T 13-2	0.5077	2.668	1.973	5.796	0.8078	9.901	0.2357	41.2
T 6-2	0.495	2.567	2.032	5.623	0.7971	9.781	0.25	54.5
T 9-2	0.3401	2.199	2.119	5.71	0.6888	10.14	0.3816	62
T 8-2	0.4384	2.04	2.266	4.747	0.737	9.194	0.3398	34
T 1-2	0.3913	2.039	1.587	4.114	0.7008	6.584	0.4095	35
T 6-1	0.3773	2.005	1.643	4.168	0.6892	6.764	0.2551	36.2
T 14-1	0.3035	2.023	1.512	4.625	0.6421	7.211	0.2624	39
T 4-1	0.3463	1.9	1.454	3.865	0.657	5.997	0.3057	88
T a-4	0.394	1.711	1.606	3.391	0.6712	5.576	0.3929	24
T 15-1	0.5534	1.715	0.8001	1.908	0.7532	2.546	0.291	14
T a-3	0.6685	1.703	0.6903	1.558	0.8167	2.026	0.2706	9
T 10-2	0.2491	1.699	1.215	3.855	0.5627	5.648	0.5462	40.5
T 16-1	0.2659	1.602	1.376	3.669	0.565	5.596	0.4421	32.25
T 1-1	0.2653	1.279	1.109	2.687	0.5101	3.868	0.4481	29
T 4-3	0.4274	2.935	4.049	11.06	0.7932	27.36	0.185	276.3
T 5-4	0.4877	2.72	2.715	7.249	0.8053	14.41	0.1429	82.75
T 12-3	0.608	2.717	2.334	5.92	0.8564	11.08	0.1755	50
T 5-1	0.4328	2.719	2.552	7.435	0.7774	14.09	0.1549	218.5
T 3-3	0.3923	2.674	2.938	8.295	0.757	16.89	0.2109	134.8
T 10-3	0.4973	2.619	2.227	6.054	0.8019	10.96	0.2232	94
T 16-4	0.4659	2.656	1.982	6.035	0.7869	10.29	0.1455	71
T 11-2	0.6642	2.62	1.717	4.48	0.8729	7.366	0.1321	30
T 7-1	0.5614	2.491	2.584	5.79	0.8285	11.8	0.1984	59.33
T 13-3	0.529	2.552	2.085	5.438	0.8128	9.639	0.2464	63
T 6-4	0.5041	2.469	2.104	5.336	0.7966	9.537	0.1947	55

T 7-2	0.3647	2.406	3.007	7.535	0.7266	16.1	0.2486	100
T 4-2	0.3605	2.407	2.711	7.126	0.7215	14.21	0.2754	94.2
T 14-2	0.4318	2.475	1.794	5.38	0.7577	8.873	0.1855	51.5
T 5-2	0.4497	2.169	1.635	4.16	0.7451	6.737	0.3232	32
T 2-1	0.3846	2.01	1.705	4.228	0.6952	6.97	0.3681	56
T a 1	0.218	1.692	1.876	5.113	0.5476	8.643	0.5356	63

Appendix-Table 12. List of imaged samples with their location details.

SN	PLATE	Species	Stations	Latitude	Longitude	Depth [m]
1	Plate 1	*Agglutinated sp. 1*	T2-3	26.45027	55.5	21
2	Plate 1	*Thurammina papyracea*	T5-4	26.635	53.96666	28
3	Plate 1	*Haplophragmoides pusillus*	T4-1	26.33333	55.5	23
4	Plate 1	*Trochammina inflata*	MP4	26.043374	50.625523	0.02
5	Plate 1	*Migros cf flintini*	T4-3	26.43333	54.48333	18
6	Plate 1	*Migros cf flintini*	T13-2	28.55139	50.45	21
7	Plate 1	*Clavulina angularis*	MP10	26.043513	50.625367	0.4
8	Plate 2	*Gaudryina convexa*	T3-3	26.46667	54.98333	31
9	Plate 2	*Gaudryina sp. 01*	T3-3	26.46667	54.98333	31
10	Plate 2	*Gaudryina sp. 02*	T3-3	26.46667	54.98333	31
11	Plate 2	*Gaudryina sp. 03*	T5-1	26.13333	54.48333	24
12	Plate 2	*Gaudryina attenuata*	T4-2	25.83333	54.96666	22
13	Plate 2	*Gaudryina sp. 04*	T4-2	25.83333	54.96666	22
14	Plate 2	*Gaudryina sp. 05*	T4-2	25.83333	54.96666	22
15	Plate 2	*Gaudryina sp. 06*	T4-2	25.83333	54.96666	22
16	Plate 3	*Textularia sp. 26*	T16-4	29.70111	49.90139	21
17	Plate 3	*Textularia sp. 24*	T4-3	26.43333	54.48333	18
18	Plate 3	*Textularia sp. 22*	T6-4	25.55248	53.98485	21
19	Plate 3	*Textularia sp. 25*	T4-3	26.43333	54.48333	18
20	Plate 3	*Textularia sp. 27*	T16-4	29.70111	49.90139	21
21	Plate 3	*Textularia sp. 21*	T5-1	26.13333	54.48333	24
22	Plate 3	*Textularia sp. 28*	Ta-1	26.54	56	NA
23	Plate 3	*Textularia sp. 23*	T13-2	28.55139	50.45	21
24	Plate 4	*Textularia conica*	T4-3	26.43333	54.48333	18
25	Plate 4	*Sahulia barkeri*	T4-2	25.83333	54.96666	22
26	Plate 4	*Sahulia cf. S. barkeri*	T3-3	26.46667	54.98333	31
27	Plate 4	*Sahulia cf. S. barkeri*	T16-4	29.70111	49.90139	21
28	Plate 4	*Sahulia cf. S. barkeri*	T16-4	29.70111	49.90139	21
29	Plate 4	*Textularia sp. 19*	T4-3	26.43333	54.48333	18
30	Plate 4	*Textularia sp. 20*	T4-3	26.43333	54.48333	18
31	Plate 4	*Textularia sp. 18*	T4-2	25.83333	54.96666	22
32	Plate 5	*Spiroplectinella sagittula*	T4-2	25.83333	54.96666	22
33	Plate 5	*Textularia sp. 17*	T4-2	25.83333	54.96666	22
34	Plate 5	*Textularia goessi*	T4-2	25.83333	54.96666	22
35	Plate 5	*Textularia sp. 16*	T3-3	26.46667	54.98333	31
36	Plate 5	*Textularia cf T. kerimbaensis*	T4-3	26.43333	54.48333	18
37	Plate 5	*Textularia kerimbaensis*	T2-1	26.56749	55.98244	21.2
38	Plate 5	*Textularia pala*	T2-1	26.56749	55.98244	21.2

39	Plate 5	*Textularia pala*	T4-2	25.83333	54.96666	22
40	Plate 6	*Spiroplectammina earlandi*	T3-3	26.46667	54.98333	31
41	Plate 6	*Spiroplectammina earlandi*	T3-3	26.46667	54.98333	31
42	Plate 6	*Textularia sp. 15*	T6-2	25.99755	54.00503	20
43	Plate 6	*Textularia sp. 08*	T5-1	26.13333	54.48333	24
44	Plate 6	*Textularia sp. 07*	T5-1	26.13333	54.48333	24
45	Plate 6	*Textularia sp. 04*	T12-3	28.03334	50.5	21
46	Plate 6	*Textularia sp. 06*	T4-3	26.43333	54.48333	18
47	Plate 6	*Textularia cf T. foliacea*	T16-4	29.70111	49.90139	21
48	Plate 7	*Spiroplectammina earlandi*	T4-2	25.83333	54.96666	22
49	Plate 7	*Textularia sp. 10*	T5-2	25.97499	54.48333	24
50	Plate 7	*Textularia sp. 05*	T3-3	26.46667	54.98333	31
51	Plate 7	*Textularia sp. 09*	T5-1	26.13333	54.48333	24
52	Plate 7	*Textularia sp. 14*	T5-4	26.635	53.96666	28
53	Plate 7	*Textularia cf T. foliacea*	T16-4	29.70111	49.90139	21
54	Plate 8	*Spirotextularia cf S. floridana*	T3-3	26.46667	54.98333	31
55	Plate 8	*Spirotextularia cf S. floridana*	T4-2	25.83333	54.96666	22
56	Plate 8	*Textularia stricta*	T3-3	26.46667	54.98333	31
57	Plate 8	*Textularia stricta*	T5-4	26.635	53.96666	28
58	Plate 8	*Spirotextularia cf S. floridana*	T5-4	26.635	53.96666	28
59	Plate 8	*Spirotextularia cf S. floridana*	T6-4	25.55248	53.98485	21
60	Plate 9	*Textularia sp. 12*	T5-2	25.97499	54.48333	24
61	Plate 9	*Textularia foliacea*	T16-4	29.70111	49.90139	21
62	Plate 9	*Textularia cf T. foliacea occidentalis*	T5-1	26.13333	54.48333	24
63	Plate 9	*Textularia cushmani*	T14-2	29.05	50.23333	23
64	Plate 9	*Textularia foliacea*	T16-4	29.70111	49.90139	21
65	Plate 9	*Textularia sp. 01*	T4-2	25.83333	54.96666	22
66	Plate 9	*Textularia sp. 03*	T11-2	27.66666	51.13473	20
67	Plate 9	*Textularia sp. 13*	T5-4	26.635	53.96666	28
68	Plate 10	*Textularia foliacea oceanica*	T5-4	26.635	53.96666	28
69	Plate 10	*Textularia foliacea oceanica*	T6-2	25.99755	54.00503	20
70	Plate 10	*Textularia cf T. foliacea occidentalis*	T5-1	26.13333	54.48333	24
71	Plate 10	*Textularia sp. 02*	T4-3	26.43333	54.48333	18
72	Plate 10	*Textularia sp. 11*	T5-2	25.97499	54.48333	24
73	Plate 11	*Ammonia tepida*	MP6	26.043403	50.625499	0.04
74	Plate 11	*Ammonia cf. A. tepida*	T4-1	26.33333	55.5	23
75	Plate 11	*Ammonia cf A. tepida*	T4-1	26.33333	55.5	23
76	Plate 11	*Ammonia sp. 1*	MP14	26.044472	50.626444	1
77	Plate 11	*Ammonia convexa*	T2-3	26.45027	55.5	21
78	Plate 11	*Ammonia cf. A. aberdoveyensis*	T1-1	NA	NA	20
79	Plate 11	*Ammonia convexa*	T6-1	26.29999	53.98416	23
80	Plate 11	*Ammonia convexa*	AS10	26.043669	50.625141	0.4

81	Plate 12	*Ammonia faceta*	T10-2	27.45139	51.70139	22
82	Plate 12	*Ammonia cf. A. aberdoveyensis*	T1-1	NA	NA	20
83	Plate 12	*Ammonia cf A. convexa*	T12-3	28.03334	50.5	21
84	Plate 12	*Ammonia sp. 1*	T11-2	27.66666	51.13473	20
85	Plate 12	*Ammonia sp. 2*	Ta-4	26.54	56.95028	NA
86	Plate 12	*Ammonia sp. 3*	T11-2	27.66666	51.13473	20
87	Plate 12	*Ammonia sp. 4*	MP14	26.044472	50.626444	1
88	Plate 12	*Ammonia sp 5*	T12-3	28.03334	50.5	21
89	Plate 13	*Elphidium fichtellianum*	MP6	26.043403	50.625499	0.04
90	Plate 13	*Elphidium fichtellianum*	T5-1	26.13333	54.48333	24
91	Plate 13	*Elphidium fichtellianum*	T5-1	26.13333	54.48333	24
92	Plate 13	*Elphidium gerthi*	AS10	26.043669	50.625141	0.4
93	Plate 13	*Elphidium maorium*	MP6	26.043403	50.625499	0.04
94	Plate 13	*Elphidium gerthi*	T9-2	27.11667	52.18472	21
95	Plate 13	*Elphidium gerthi*	T9-2	27.11667	52.18472	21
96	Plate 14	*Elphidium craticulatum*	T6-2	25.99755	54.00503	20
97	Plate 14	*Elphidium tongaense*	MP14	26.044472	50.626444	1
98	Plate 14	*Elphidium macelliforme*	AS10	26.043669	50.625141	0.4
99	Plate 14	*Elphidium advenum*	MP14	26.044472	50.626444	1
100	Plate 14	*Elphidium advenum*	MP14	26.044472	50.626444	1
101	Plate 14	*Elphidium advenum*	MP14	26.044472	50.626444	1
102	Plate 14	*Elphidium advenum*	T9-2	27.11667	52.18472	21
103	Plate 14	*Elphidium advenum*	T1-1	NA	NA	20
104	Plate 15	*Elphidium neosimplex*	T10-2	27.45139	51.70139	22
105	Plate 15	*Elphidium neosimplex*	T10-2	27.45139	51.70139	22
106	Plate 15	*Elphidium neosimplex*	T10-3	27.2	51.41806	25
107	Plate 15	*Elphidium neosimplex*	T14-1	29.16667	50.53333	22
108	Plate 15	*Elphidium neosimplex*	T16-1	29.33334	49.36666	16
109	Plate 15	*Elphidium neosimplex*	T10-3	27.2	51.41806	25
110	Plate 15	*Elphidium neosimplex*	T16-1	29.33334	49.36666	16
111	Plate 15	*Elphidium neosimplex*	T10-2	27.45139	51.70139	22
112	Plate 16	*Elphidium cf. hawkesburiensis*	AS10	26.043669	50.625141	0.4
113	Plate 16	*Parrellina hispidula*	T5-1	26.13333	54.48333	24
114	Plate 16	*Parrellina hispidula*	T5-1	26.13333	54.48333	24
115	Plate 16	*Parrellina hispidula*	T5-1	26.13333	54.48333	24
116	Plate 16	*Parrellina hispidula*	T5-1	26.13333	54.48333	24
117	Plate 16	*Parrellina hispidula*	T3-3	26.46667	54.98333	31
119	Plate 17	*Glabratella sp. 1*	MP4	26.043374	50.625523	0.02
120	Plate 17	*Glabratellina sp. 1*	MP6	26.043403	50.625499	0.04
121	Plate 17	*Gavelinopsis sp*	T2-3	26.45027	55.5	21
122	Plate 17	*Rosalina bradyi*	T5-1	26.13333	54.48333	24
123	Plate 17	*Rosalina bradyi*	T5-1	26.13333	54.48333	24

124	Plate 17	*Rosalina bradyi*	MP6	26.043403	50.625499	0.04
125	Plate 17	*Rosalina bradyi*	T5-1	26.13333	54.48333	24
126	Plate 17	*Rosalina sp.*	T7-1	26.7	53.48333	21
127	Plate 18	*Cymbaloporetta bradyi*	MP14	26.044472	50.626444	1
128	Plate 18	*Cymbaloporetta cf. C. bradyi*	MP6	26.043403	50.625499	0.04
129	Plate 18	*Cymbaloporetta cf. C. bradyi*	T4-3	26.43333	54.48333	18
130	Plate 18	*Cymbaloporetta sp.*	T6-4	25.55248	53.98485	21
131	Plate 18	*Acervulina mahabeti*	T4-3	26.43333	54.48333	18
132	Plate 18	*Acervulina mahabeti*	T4-3	26.43333	54.48333	18
133	Plate 18	*Planorbulina sp*	T4-3	26.43333	54.48333	18
134	Plate 18	*Rosalina sp*	T7-1	26.7	53.48333	21
135	Plate 19	*Rosalina sp. 05*	T9-2	27.11667	52.18472	21
136	Plate 19	*Rosalina sp. 02*	T5-1	26.13333	54.48333	24
137	Plate 19	*Rosalina sp. 04*	Ta-4	26.54	56.95028	NA
138	Plate 19	*Porosononion sp. 1*	T10-2	27.45139	51.70139	22
139	Plate 19	*Porosononion sp. 2*	T4-1	26.33333	55.5	23
140	Plate 19	*Porosononion sp. 3*	T10-2	27.45139	51.70139	22
141	Plate 19	*Porosononion sp. 4*	T10-2	27.45139	51.70139	22
142	Plate 19	*Epondes sp.*	AS10	26.043669	50.625141	0.4
143	Plate 20	*Asterorotalia dentata*	T15-1	29.61667	50.28445	19
144	Plate 20	*Asterorotalia dentata*	T4-1	26.33333	55.5	23
145	Plate 20	*Asterorotalia inflata*	T7-2	26.38334	53.46667	21
146	Plate 20	*Asterorotalia sp. 4*	Ta-4	26.54	56.95028	NA
147	Plate 20	*Asterorotalia sp. 3*	T9-2	27.11667	52.18472	21
148	Plate 20	*Asterorotalia sp.1*	T2-3	26.45027	55.5	21
149	Plate 20	*Asterorotalia sp.6*	T7-2	26.38334	53.46667	21
150	Plate 20	*Asterorotalia sp. 7*	Ta-1	26.54	56	NA
151	Plate 21	*Asterorotalia sp.8*	T4-1	26.33333	55.5	23
152	Plate 21	*Asterorotalia sp.9*	T6-1	26.29999	53.98416	23
153	Plate 21	*Asterorotalia sp.10*	T4-3	26.43333	54.48333	18
154	Plate 21	*Asterorotalia gaimardi*	T4-3	26.43333	54.48333	18
155	Plate 21	*Challengerella sp. 2*	T3-3	26.46667	54.98333	31
156	Plate 21	*Asterorotalia cf A. gaimardi*	T3-3	26.46667	54.98333	31
157	Plate 21	*Challengerella cf. C. persica*	T4-2	25.83333	54.96666	22
158	Plate 21	*Challengerella persica*	T2-1	26.56749	55.98244	21.2
159	Plate 22	*Uvigerina cf. U. peregrina*	Ta-1	26.54	56	NA
160	Plate 22	*Pyramidulina sp. 01*	T5-2	25.97499	54.48333	24
161	Plate 22	*Challengerella sp 01*	T4-2	25.83333	54.96666	22
162	Plate 22	*Uvigerina cf. U. proboscidea*	Ta-1	26.54	56	NA
163	Plate 22	*Amphisterigina lessonii*	T5-1	26.13333	54.48333	24
164	Plate 22	*Assilina sp*	T7-1	26.7	53.48333	21
165	Plate 22	*Challengerella sp. 03*	T4-2	25.83333	54.96666	22

166	Plate 23	*(?) Oolina sp*	T10-2	27.45139	51.70139	22
167	Plate 23	*(?) Oolina sp*	T10-2	27.45139	51.70139	22
168	Plate 23	*Glandulina laevigata*	T14-2	29.05	50.23333	23
169	Plate 23	*Glandulina cf. G. laevigata*	T4-3	26.43333	54.48333	18
170	Plate 23	*Glandulina sp. 2*	Ta-4	26.54	56.95028	NA
171	Plate 23	*Fissurina cf F. bispinata*	T14-1	29.16667	50.53333	22
172	Plate 23	*Fissurina lucida*	T5-4	26.635	53.96666	28
173	Plate 23	*Fissurina sp. 01*	T7-2	26.38334	53.46667	21
174	Plate 24	*Lagena cf. L. strumosa*	T1-2	NA	NA	NA
175	Plate 24	*Lagena cf. L. semistriata*	T14-1	29.16667	50.53333	22
176	Plate 24	*Lagena cf. L. strumosa*	T7-2	26.38334	53.46667	21
177	Plate 24	*Lagena semistriata*	T1-1	NA	NA	20
178	Plate 24	*Lagena strumosa*	T9-2	27.11667	52.18472	21
179	Plate 24	*Lagena sp. 01*	T6-1	26.29999	53.98416	23
180	Plate 24	*Lagena sp. 02*	T10-3	27.2	51.41806	25
181	Plate 24	*Lagena sp. 03*	T10-3	27.2	51.41806	25
182	Plate 25	*(?) Praebulimina sp.*	Ta-1	26.54	56	NA
183	Plate 25	*Cancaris cf. C. bubnanensis*	T6-4	25.55248	53.98485	21
184	Plate 25	*Cancaris bubnanensis*	T3-3	26.46667	54.98333	31
185	Plate 25	*Cancaris cf. C. bubnanensis*	T5-4	26.635	53.96666	28
186	Plate 25	*Cancaris cf. C. bubnanensis*	T5-1	26.13333	54.48333	24
187	Plate 25	*Cancaris cf. C. bubnanensis*	T5-4	26.635	53.96666	28
188	Plate 25	*Cancris cf. C. oblongus*	T7-2	26.38334	53.46667	21
189	Plate 25	*Cancris cf. C. oblongus*	T12-3	28.03334	50.5	21
190	Plate 26	*Cancaris cf. C. auricularis*	T1-2	NA	NA	NA
191	Plate 26	*Cancaris cf. C. auricularis*	T4-3	26.43333	54.48333	18
192	Plate 26	*Cancaris cf. C. auricularis*	T1-2	NA	NA	NA
193	Plate 26	*Cancaris cf. C. auricularis*	T6-1	26.29999	53.98416	23
194	Plate 26	*Hanzawaia sp*	T7-1	26.7	53.48333	21
195	Plate 26	*Lobatula lobatula*	T4-2	25.83333	54.96666	22
196	Plate 26	*Hanzawaia sp. 2*	T4-3	26.43333	54.48333	18
197	Plate 26	*Hanzawaia sp. 3*	T4-3	26.43333	54.48333	18
198	Plate 27	*Hanzawaia sp. 4*	T4-3	26.43333	54.48333	18
199	Plate 27	*Hanzawaia sp. 5*	T10-3	27.2	51.41806	25
200	Plate 27	*Hanzawaia sp. 6*	T13-2	28.55139	50.45	21
201	Plate 27	*Hanzawaia sp. 7*	T13-3	28.36914	50.03166	20
202	Plate 27	*Cibicidoides sp.*	T3-3	26.46667	54.98333	31
203	Plate 27	*Hanzawaia sp.*	T3-3	26.46667	54.98333	31
204	Plate 27	*Cibicides cf. C. refugens*	T5-2	25.97499	54.48333	24
205	Plate 27	*Cibicides cf. C. phillipensis*	T2-1	26.56749	55.98244	21.2
206	Plate 28	*Cibicides cf. C. refulgens*	T5-2	25.97499	54.48333	24
207	Plate 28	*Cibicides cf. C. refulgens*	T5-2	25.97499	54.48333	24

208	Plate 28	*Cibicides sp.*	T7-1	26.7	53.48333	21
209	Plate 28	*Cibicidoides sp. 1*	T13-3	28.36914	50.03166	20
210	Plate 28	*Cibicides cf. C. refulgens*	T4-2	25.83333	54.96666	22
211	Plate 28	*Cibicides cf. C. refulgens*	T4-2	25.83333	54.96666	22
212	Plate 29	*Bulimina cf. B. biserialis*	T5-2	25.97499	54.48333	24
213	Plate 29	*Bulimina cf. B. biserialis*	T10-3	27.2	51.41806	25
214	Plate 29	*Bulimina sp. 01*	T7-2	26.38334	53.46667	21
215	Plate 29	*Bulimina cf. B. biserialis*	T7-2	26.38334	53.46667	21
216	Plate 29	*Bulimina cf. B. biserialis*	T12-3	28.03334	50.5	21
217	Plate 29	*Bulimina sp. 02*	T7-2	26.38334	53.46667	21
218	Plate 29	*Bulimina sp. 04*	T16-1	29.33334	49.36666	16
219	Plate 29	*Bulimina cf. B. marginata*	T2-3	26.45027	55.5	21
220	Plate 30	*Bulimina cf. B. marginata*	T15-1	29.61667	50.28445	19
221	Plate 30	*Bulimina sp. 03*	T10-3	27.2	51.41806	25
222	Plate 30	*Fursenkoina sp. 02*	T13-2	28.55139	50.45	21
223	Plate 30	*Fursenkoina sp. 04*	T7-2	26.38334	53.46667	21
224	Plate 30	*Fursenkoina sp. 03*	T9-2	27.11667	52.18472	21
225	Plate 30	*Sagrinella lobata lobata*	T7-1	26.7	53.48333	21
226	Plate 30	*Sagrinella lobata lobata*	T7-1	26.7	53.48333	21
227	Plate 30	*Sigmavirgulina sp. 02*	T12-3	28.03334	50.5	21
228	Plate 30	*Sigmavirgulina sp. 01*	T11-2	27.66666	51.13473	20
229	Plate 30	*Sigmavirgulina sp. 02*	T4-3	26.43333	54.48333	18
230	Plate 30	*Sigmavirgulina sp. 03*	T7-1	26.7	53.48333	21
231	Plate 31	*Loxostomina costulata*	T10-3	27.2	51.41806	25
232	Plate 31	*Loxostomina sp. 04*	T5-1	26.13333	54.48333	24
233	Plate 31	*Loxostomina sp. 03*	T10-3	27.2	51.41806	25
234	Plate 31	*Brizalina subspathulata*	T7-2	26.38334	53.46667	21
235	Plate 31	*Brazilina cf. B. subspathulata*	T9-2	27.11667	52.18472	21
236	Plate 31	*Brazilina cf. B. subspathulata 01*	T9-2	27.11667	52.18472	21
237	Plate 31	*Brazilina cf. B. subspathulata 03*	T10-3	27.2	51.41806	25
238	Plate 31	*Brizilina cf. B. striatula*	T1-2	NA	NA	NA
239	Plate 31	*Brizalina striatula*	Ta-3	26.54	57	NA
240	Plate 31	*Brazilina striatula*	T4-1	26.33333	55.5	23
241	Plate 32	*Brizalina striatula*	T10-2	27.45139	51.70139	22
242	Plate 32	*Brizalina striatula*	T10-2	27.45139	51.70139	22
243	Plate 32	*Bolivina cf. B. suezensis*	T8-2	26.68472	52.75	24
244	Plate 32	*Bolivina cf. B. suezensis*	Ta-4	26.54	56.95028	NA
245	Plate 32	*Bolivina cf. B. suezensis*	Ta-4	26.54	56.95028	NA
246	Plate 32	*Bolivina cf. B. suezensis*	T11-2	27.66666	51.13473	20
247	Plate 32	*Bolivina cf. B. plicata*	T1-2	NA	NA	NA
248	Plate 32	*Bolivina cf. B. persiensis*	T7-2	26.38334	53.46667	21
249	Plate 32	*Bolivina cf. B. persiensis*	T7-2	26.38334	53.46667	21

250	Plate 33	*Bolivina cf. B. persiensis*	T8-2	26.68472	52.75	24
251	Plate 33	*Bolivina cf. B. persiensis*	T8-2	26.68472	52.75	24
252	Plate 33	*Bolivinellina translucens*	T9-2	27.11667	52.18472	21
253	Plate 33	*Bolivinellina translucens*	T7-2	26.38334	53.46667	21
254	Plate 33	*Bolivinellina translucens 07*	T7-2	26.38334	53.46667	21
255	Plate 33	*Bolivinellina translucens*	T8-2	26.68472	52.75	24
256	Plate 33	*Bolivinellina cf. B. translucens*	T13-2	28.55139	50.45	21
257	Plate 33	*Bolivinellina translucens*	T5-4	26.635	53.96666	28
258	Plate 33	*Bolivina cf. B. persiensis*	Ta-4	26.54	56.95028	NA
259	Plate 33	*Bolivina cf. B. striatula*	MP6	26.043403	50.625499	0.04
260	Plate 33	*Trimosina cf. T. milletti multispinata*	T1-1	NA	NA	20
261	Plate 34	*Nonion cf. N. depressulus*	T16-1	29.33334	49.36666	16
262	Plate 34	*Nonion sp.*	T13-3	28.36914	50.03166	20
263	Plate 34	*Pseudononion japonicum*	T1-1	NA	NA	20
264	Plate 34	*Nonion sp. 03*	T14-1	29.16667	50.53333	22
265	Plate 34	*Nonionella cf. N. labradorica*	T6-1	26.29999	53.98416	23
266	Plate 34	*Nonion sp. 04*	T6-1	26.29999	53.98416	23
267	Plate 34	*Nonionella cf. N. labradorica*	T1-1	NA	NA	20
268	Plate 34	*Nonionella cf. N. iridea*	T2-3	26.45027	55.5	21
269	Plate 35	*Pseudonubeculina arabica*	T6-2	25.99755	54.00503	20
270	Plate 35	*Pseudonubeculina arabica*	T6-2	25.99755	54.00503	20
271	Plate 35	*Nubeculina sp.*	T4-2	25.83333	54.96666	22
272	Plate 35	*Pseudonubeculina arabica*	T4-2	25.83333	54.96666	22
273	Plate 35	*Agglutinella aggutinans*	MP6	26.043403	50.625499	0.04
274	Plate 35	*Agglutinella aggutinans*	MP12	26.043617	50.625221	0.02
275	Plate 35	*Agglutinella arenata*	MP6	26.043403	50.625499	0.04
276	Plate 35	*Agglutinella arenata*	AS10	26.043669	50.625141	0.4
277	Plate 36	*Agglutinella compressa*	AS10	26.043669	50.625141	0.4
278	Plate 36	*Agglutinella soriformis*	MP14	26.044472	50.626444	1
279	Plate 36	*Siphonaperta pittensis*	MP14	26.044472	50.626444	1
280	Plate 36	*Siphonaperta pittensis*	T4-3	26.43333	54.48333	18
281	Plate 36	*Siphonaperta sp. 04*	T4-3	26.43333	54.48333	18
282	Plate 36	*Siphonaperta sp. 08*	T6-4	25.55248	53.98485	21
283	Plate 36	*Siphonaperta sp. 09*	T8-2	26.68472	52.75	24
284	Plate 36	*Siphonaperta sp. 10*	T9-2	27.11667	52.18472	21
285	Plate 37	*Siphonaperta sp. 11*	T9-2	27.11667	52.18472	21
286	Plate 37	*Siphonaperta sp. 12*	T14-2	29.05	50.23333	23
287	Plate 37	*Siphonaperta agglutinans*	T7-2	26.38334	53.46667	21
288	Plate 37	*Sigmoilopsis sp. 06*	T5-1	26.13333	54.48333	24
289	Plate 37	*Sigmoilopsis sp. 01*	T3-3	26.46667	54.98333	31
290	Plate 37	*Sigmoilopsis sp. 02*	T3-3	26.46667	54.98333	31
291	Plate 37	*Sigmoilopsis cf. S. herzensteini*	T14-2	29.05	50.23333	23

292	Plate 37	*Sigmoilopsis cf. S. herzensteini*	T14-2	29.05	50.23333	23
293	Plate 38	*Sigmoilopsis sp. 07*	T6-2	25.99755	54.00503	20
294	Plate 38	*Sigmoilopsis sp. 03*	T3-3	26.46667	54.98333	31
295	Plate 38	*Sigmoilopsis sp. 04*	T4-2	25.83333	54.96666	22
296	Plate 38	*Sigmoilopsis sp. 05*	T5-1	26.13333	54.48333	24
297	Plate 38	*Quinqueloculina arenata*	MP6	26.043403	50.625499	0.04
298	Plate 39	*Triloculina cf. T. serrulata*	MP10	26.043513	50.625367	0.4
299	Plate 39	*Triloculina cf. T. serrulata*	MP10	26.043513	50.625367	0.4
300	Plate 39	*Triloculina cf. T. serrulata*	MP10	26.043513	50.625367	0.4
301	Plate 39	*Triloculina cf. T. serrulata*	MP6	26.043403	50.625499	0.04
302	Plate 39	*Triloculina cf. T. serrulata*	MP2	26.043319	50.625472	0.1
303	Plate 39	*Triloculina cf. T. vespertilio*	MP6	26.043403	50.625499	0.04
304	Plate 39	*Triloculina cf. T. vespertilio*	MP14	26.044472	50.626444	1
305	Plate 39	*Triloculina cf. T. verspertilio*	MP14	26.044472	50.626444	1
306	Plate 40	*Triloculina cf. T. fichteliana*	AS10	26.043669	50.625141	0.4
307	Plate 40	*Triloculina cf. T. fichteliana*	MP4	26.043374	50.625523	0.02
308	Plate 40	*Triloculina cf. T. fichteliana*	MP10	26.043513	50.625367	0.4
309	Plate 40	*Triloculina sp. 05*	MP6	26.043403	50.625499	0.04
310	Plate 40	*Trilocula sp. 04*	MP14	26.044472	50.626444	1
311	Plate 40	*Triloculina sp. 02*	MP14	26.044472	50.626444	1
312	Plate 40	*Triloculina sp. 01*	MP2	26.043319	50.625472	0.1
313	Plate 40	*Triloculina marioni*	AS10	26.043669	50.625141	0.4
314	Plate 41	*Triloculina wiesneri*	T3-3	26.46667	54.98333	31
315	Plate 41	*Triloculina sp. 06*	MP14	26.044472	50.626444	1
316	Plate 41	*Triloculina fichteliana*	T7-1	26.7	53.48333	21
317	Plate 41	*Triloculina fichteliana*	T14-1	29.16667	50.53333	22
318	Plate 41	*Triloculina* sp. 12	T2-1	26.56749	55.98244	21.2
319	Plate 41	*Triloculina trigonula*	T10-2	27.45139	51.70139	22
320	Plate 41	*Triloculina sp. 03*	T2-3	26.45027	55.5	21
321	Plate 41	*Triloculina sp. 01*	T2-1	26.56749	55.98244	21.2
322	Plate 42	*Triloculina tricarinata*	T5-2	25.97499	54.48333	24
323	Plate 42	*Triloculina trigonula*	AS10	26.043669	50.625141	0.4
324	Plate 42	*Triloculina cf. T. trigonula*	AS10	26.043669	50.625141	0.4
325	Plate 42	*Triloculina cf. T. trigonula*	T4-3	26.43333	54.48333	18
326	Plate 42	*Triloculina trigonula*	T16-4	29.70111	49.90139	21
327	Plate 42	*Triloculina cf. T. trigonula*	T7-2	26.38334	53.46667	21
328	Plate 42	*Triloculina plicata*	AS10	26.043669	50.625141	0.4
329	Plate 42	*Triloculina trigonula*	T14-2	29.05	50.23333	23
330	Plate 43	*Triloculina terquemiana*	T6-2	25.99755	54.00503	20
331	Plate 43	*Triloculina terquemiana*	T4-3	26.43333	54.48333	18
332	Plate 43	*Triloculina terquemiana*	T5-4	26.635	53.96666	28
333	Plate 43	*Triloculina terquemiana*	T3-3	26.46667	54.98333	31

334	Plate 43	*Triloculina cf. T. affinis*	MP6	26.043403	50.625499	0.04
335	Plate 43	*Triloculina sp 04*	T3-3	26.46667	54.98333	31
336	Plate 43	*Triloculina elongotricarinata*	T4-2	25.83333	54.96666	22
337	Plate 43	*Triloculina elongotricarinata*	T3-3	26.46667	54.98333	31
338	Plate 44	*Spiroloculina indica*	AS10	26.043669	50.625141	0.4
339	Plate 44	*Spiroloculina indica*	AS10	26.043669	50.625141	0.4
340	Plate 44	*Spiroloculina indica*	MP6	26.043403	50.625499	0.04
341	Plate 44	*Spiroloculina indica*	AS10	26.043669	50.625141	0.4
342	Plate 44	*Spiroloculina indica*	MP2	26.043319	50.625472	0.1
343	Plate 44	*Spiroloculina sp. 04*	AS10	26.043669	50.625141	0.4
344	Plate 44	*Spiroloculina sp. 01*	AS10	26.043669	50.625141	0.4
345	Plate 44	*Spiroloculina attenuata*	AS10	26.043669	50.625141	0.4
346	Plate 45	*Spiroloculina communis*	T1-2	NA	NA	NA
347	Plate 45	*Spiroloculina sp. 09*	MP6	26.043403	50.625499	0.04
348	Plate 45	*Spiroloculina rotunda*	T4-1	26.33333	55.5	23
349	Plate 45	*Spiroloculina rotunda*	T12-3	28.03334	50.5	21
350	Plate 45	*Spiroloculina rotunda*	T15-1	29.61667	50.28445	19
351	Plate 45	*Spiroloculina rotunda*	T16-1	29.33334	49.36666	16
352	Plate 45	*Spiroloculina rotunda*	T16-4	29.70111	49.90139	21
353	Plate 45	*Spiroloculina rotunda*	Ta-1	26.54	56	NA
354	Plate 46	*Spiroloculina rotunda*	Ta-1	26.54	56	NA
355	Plate 46	*Spiroloculina rotunda*	AS10	26.043669	50.625141	0.4
356	Plate 46	*Spiroloculina rotunda*	T1-1	NA	NA	20
357	Plate 46	*Spiroloculina sp 02*	AS10	26.043669	50.625141	0.4
358	Plate 46	*Spiroloculina excavata*	AS10	26.043669	50.625141	0.4
359	Plate 46	*Spiroloculina sp. 08*	MP6	26.043403	50.625499	0.04
360	Plate 46	*Spiroloculina communis*	MP10	26.043513	50.625367	0.4
361	Plate 46	*Spiroloculina sp. 07*	MP6	26.043403	50.625499	0.04
362	Plate 47	*Spiroloculina cf. S. depressa*	T4-2	25.83333	54.96666	22
363	Plate 47	*Spiroloculina cf. S. depressa*	T16-1	29.33334	49.36666	16
364	Plate 47	*Spiroloculina sp. 05*	T16-4	29.70111	49.90139	21
365	Plate 47	*Spiroloculina sp. 02*	T10-3	27.2	51.41806	25
366	Plate 47	*Spiroloculina sp. 04*	T14-2	29.05	50.23333	23
367	Plate 47	*Spiroloculina sp. 08*	MP4	26.043374	50.625523	0.02
368	Plate 47	*Spiroloculina pulchella*	AS10	26.043669	50.625141	0.4
369	Plate 47	*Spiroloculina cf. S. nummiformis*	AS10	26.043669	50.625141	0.4
370	Plate 48	*Spiroloculina cf. S. communis*	AS10	26.043669	50.625141	0.4
371	Plate 48	*Spiroloculina sp. 05*	MP14	26.044472	50.626444	1
372	Plate 48	*Spiroloculina sp. 01*	T7-2	26.38334	53.46667	21
373	Plate 48	*Spiroloculina sp. 10*	MP6	26.043403	50.625499	0.04
374	Plate 48	*Spiroloculina sp. 03*	AS10	26.043669	50.625141	0.4
375	Plate 48	*Spiroloculina subimpressa*	T4-2	25.83333	54.96666	22

376	Plate 48	*Spiroloculina subimpressa*	T6-2	25.99755	54.00503	20
377	Plate 48	*Spiroloculina subimpressa*	T3-3	26.46667	54.98333	31
378	Plate 49	*Spiroloculina sp. 06*	T16-4	29.70111	49.90139	21
379	Plate 49	*Spiroloculina sp. 03*	T13-2	28.55139	50.45	21
380	Plate 49	*Spiroloculina hadai*	AS10	26.043669	50.625141	0.4
381	Plate 49	*Spiroloculina elegantissima*	T3-3	26.46667	54.98333	31
382	Plate 49	*Spiroloculina regularis*	Ta-1	26.54	56	NA
383	Plate 50	*Adelosina sp. 01*	T14-2	29.05	50.23333	23
384	Plate 50	*Adelosina sp. 03*	T4-3	26.43333	54.48333	18
385	Plate 50	*Adelosina sp. 02*	T7-1	26.7	53.48333	21
386	Plate 50	*Adelosina laevigata*	T4-2	25.83333	54.96666	22
387	Plate 50	*Adelosina sp. 05*	T12-3	28.03334	50.5	21
388	Plate 50	*Adelosina sp. 02*	T4-3	26.43333	54.48333	18
389	Plate 50	*Adelosina sp. 04*	T6-4	25.55248	53.98485	21
390	Plate 50	*Adelosina sp. 10*	T3-3	26.46667	54.98333	31
391	Plate 51	*Adelosina cf. A. mediterranensis*	MP10	26.043513	50.625367	0.4
392	Plate 51	*Adelosina mediterranensis*	T7-1	26.7	53.48333	21
393	Plate 51	*Adelosina sp. 07*	T14-1	29.16667	50.53333	22
394	Plate 51	*Adelosina sp. 01*	T13-2	28.55139	50.45	21
395	Plate 51	*Adelosina sp. 06*	T13-3	28.36914	50.03166	20
396	Plate 51	*Pygro phlegeri*	T4-2	25.83333	54.96666	22
397	Plate 51	*Pygro sarsi*	T14-2	29.05	50.23333	23
398	Plate 51	*Milolinella cf. M. hybrida*	AS10	26.043669	50.625141	0.4
399	Plate 52	*Miliolinella cf. M. hybrida*	AS10	26.043669	50.625141	0.4
400	Plate 52	*Miliolinella cf. M. hybrida*	AS10	26.043669	50.625141	0.4
401	Plate 52	*Miliolinella cf. M. hybrida*	MP6	26.043403	50.625499	0.04
402	Plate 52	*Miliolinella cf. M. hybrida*	MP6	26.043403	50.625499	0.04
403	Plate 52	*Miliolinella sp. 04*	MP14	26.044472	50.626444	1
404	Plate 52	*Miliolinella sp. 02*	MP12	26.043617	50.625221	0.02
405	Plate 52	*Miliolinella sp. 03*	MP14	26.044472	50.626444	1
406	Plate 52	*Miliolinella cf. M. circularis*	MP12	26.043617	50.625221	0.02
407	Plate 53	*Miliolinella chuckchiensis*	T4-3	26.43333	54.48333	18
408	Plate 53	*Miliolinella chuckchiensis*	T14-2	29.05	50.23333	23
409	Plate 53	*Miliolinella sp. 03*	T14-2	29.05	50.23333	23
410	Plate 53	*Miliolinella chuckchiensis*	T4-2	25.83333	54.96666	22
411	Plate 53	*Sigmamiliolinella australis*	T5-1	26.13333	54.48333	24
412	Plate 53	*Flintina* sp. 1	MP14	26.044472	50.626444	1
413	Plate 53	*Flintina* sp. 2	Ta-1	26.54	56	NA
414	Plate 53	*Pseudotriloculina sp.*	AS10	26.043669	50.625141	0.4
415	Plate 54	*Lachnella subpolygona*	AS10	26.043669	50.625141	0.4
416	Plate 54	*Quinqueloculina cf. Q. distorqueata*	MP4	26.043374	50.625523	0.02
417	Plate 54	*Lachlanella corrugata*	AS10	26.043669	50.625141	0.4

418	Plate 54	*Pseudotriloculina hottingeri*	AS10	26.043669	50.625141	0.4
419	Plate 54	*Pseudotriloculina hottingeri*	MP14	26.044472	50.626444	1
420	Plate 54	*Pseudotriloculina hottingeri*	MP14	26.044472	50.626444	1
421	Plate 54	*Pseudotriloculina hottingeri*	MP12	26.043617	50.625221	0.02
422	Plate 54	*Pseudotriloculina hottingeri*	MP6	26.043403	50.625499	0.04
423	Plate 55	*Pseudotriloculina subgranulata*	MP6	26.043403	50.625499	0.04
424	Plate 55	*Pseudotriloculina subgranulata*	AS10	26.043669	50.625141	0.4
425	Plate 55	*Pseudotriloculina subgranulata*	AS10	26.043669	50.625141	0.4
426	Plate 55	*Pseudotriloculina subgranulata*	AS10	26.043669	50.625141	0.4
427	Plate 55	*Cycloforina carinata*	MP2	26.043319	50.625472	0.1
428	Plate 55	*Cycloforina quinqecarinata*	MP12	26.043617	50.625221	0.02
429	Plate 55	*Quinqueloculina sp.*	MP2	26.043319	50.625472	0.1
430	Plate 55	*Quinqueloculina sp.*	MP14	26.044472	50.626444	1
431	Plate 56	*Coscinospira arienatus*	MP4	26.043374	50.625523	0.02
432	Plate 56	*Coscinospira arienatus*	MP4	26.043374	50.625523	0.02
433	Plate 56	*Coscinospira arienatus*	AS10	26.043669	50.625141	0.4
434	Plate 56	*Conscinopira sp.*	AS10	26.043669	50.625141	0.4
435	Plate 56	*Coscinospira hemprichii*	MP14	26.044472	50.626444	1
436	Plate 56	*Coscinospira hemprichii*	AS10	26.043669	50.625141	0.4
437	Plate 56	*Coscinospira hemprichii*	MP14	26.044472	50.626444	1
438	Plate 57	*Coscinospira hemprichii*	MP4	26.043374	50.625523	0.02
439	Plate 57	*Coscinospira hemprichii* juvenile	MP14	26.044472	50.626444	1
440	Plate 57	*Peneroplis sp.*	AS10	26.043669	50.625141	0.4
441	Plate 57	*Peneroplis sp.*	AS10	26.043669	50.625141	0.4
442	Plate 57	*Peneroplis sp.*	MP14	26.044472	50.626444	1
443	Plate 57	*Peneroplis sp. 02*	MP14	26.044472	50.626444	1
444	Plate 58	*Peneroplis planatus*	MP4	26.043374	50.625523	0.02
445	Plate 58	*Peneroplis planatus*	MP4	26.043374	50.625523	0.02
446	Plate 58	*Articulina alticostata*	MP14	26.044472	50.626444	1
447	Plate 58	*Articulina pacifica*	MP6	26.043403	50.625499	0.04
448	Plate 58	*Vertebralina striata*	MP6	26.043403	50.625499	0.04
449	Plate 58	*Vertebralina striata*	AS10	26.043669	50.625141	0.4
450	Plate 58	*Sorites orbicularis*	MP4	26.043374	50.625523	0.02
451	Plate 58	*Sorites orbicularis*	AS10	26.043669	50.625141	0.4
452	Plate 59	*Quinqueloculina sp. 07*	AS10	26.043669	50.625141	0.4
453	Plate 59	*Quinqueloculina sp. 08*	AS10	26.043669	50.625141	0.4
454	Plate 59	*Quinqueloculina sp. 09*	AS10	26.043669	50.625141	0.4
455	Plate 59	*Quinqueloculina sp. 16*	MP2	26.043319	50.625472	0.1
456	Plate 59	*Quinqueloculina sp. 25*	MP4	26.043374	50.625523	0.02
457	Plate 59	*Quinqueloculina sp. 16*	MP14	26.044472	50.626444	1
458	Plate 59	*Quinqueloculina sp. 21*	MP14	26.044472	50.626444	1
459	Plate 59	*Quinqueloculina sp. 18*	MP14	26.044472	50.626444	1

460	Plate 60	*Quinqueloculina sp. 19*	MP14	26.044472	50.626444	1
461	Plate 60	*Quinqueloculina sp. 16*	MP14	26.044472	50.626444	1
462	Plate 60	*Quinqueloculina sp. 03*	MP14	26.044472	50.626444	1
463	Plate 60	*Quinqueloculina sp. 17*	MP14	26.044472	50.626444	1
464	Plate 60	*Quinqueloculina sp. 22*	MP14	26.044472	50.626444	1
465	Plate 60	*Quinqueloculina sp. 16*	MP14	26.044472	50.626444	1
466	Plate 60	*Quinqueloculina sp. 24*	MP14	26.044472	50.626444	1
467	Plate 60	*Quinqueloculina sp. 27*	MP14	26.044472	50.626444	1
468	Plate 61	*Quinqueloculina sp. 31*	MP14	26.044472	50.626444	1
469	Plate 61	*Quinqueloculina timorensis*	MP10	26.043513	50.625367	0.4
470	Plate 61	*Quinqueloculina stalkeri*	T2-3	26.45027	55.5	21
471	Plate 61	*Quinqueloculina sp. 36*	T7-1	26.7	53.48333	21
472	Plate 61	*Quinqueloculina sp. 34*	T7-2	26.38334	53.46667	21
473	Plate 61	*Quinqueloculina sp. 33*	T4-3	26.43333	54.48333	18
474	Plate 61	*Quinqueloculina sp. 32*	T4-3	26.43333	54.48333	18
475	Plate 61	*Quinqueloculina sp. 19*	T4-1	26.33333	55.5	23
476	Plate 62	*Quinqueloculina poeyana*	T4-3	26.43333	54.48333	18
477	Plate 62	*Quinqueloculina sp. 35*	Ta-1	26.54	56	NA
478	Plate 62	*Quinqueloculina sp. 25*	T14-1	29.16667	50.53333	22
479	Plate 62	*Quinqueloculina sp. 28*	T14-2	29.05	50.23333	23
480	Plate 62	*Quinqueloculina sp. 22*	T11-2	27.66666	51.13473	20
481	Plate 62	*Quinqueloculina sp. 21*	T5-4	26.635	53.96666	28
482	Plate 62	*Quinqueloculina sp. 12*	T4-3	26.43333	54.48333	18
483	Plate 62	*Quinqueloculina sp. 01*	T3-3	26.46667	54.98333	31
484	Plate 63	*Quinqueloculina sp. 30*	MP14	26.044472	50.626444	1
485	Plate 63	*Quinqueloculina sp. 28*	MP14	26.044472	50.626444	1
486	Plate 63	*Quinqueloculina sp. 05*	MP6	26.043403	50.625499	0.04
487	Plate 63	*Quinqueloculina sp. 01*	MP4	26.043374	50.625523	0.02
488	Plate 63	*Quinqueloculina sp. 29*	Ta-1	26.54	56	NA
489	Plate 63	*Quinqueloculina sp. 30*	Ta-1	26.54	56	NA
490	Plate 63	*Quinqueloculina sp. 31*	Ta-1	26.54	56	NA
491	Plate 63	*Quinqueloculina sp. 13*	AS10	26.043669	50.625141	0.4
492	Plate 64	*Quinqueloculina sp. 01*	T3-3	26.46667	54.98333	31
493	Plate 64	*Quinqueloculina sp. 06*	AS10	26.043669	50.625141	0.4
494	Plate 64	*Quinqueloculina lamarckiana*	AS10	26.043669	50.625141	0.4
495	Plate 64	*Quinqueloculina sp. 18*	T2-1	26.56749	55.98244	21.2
496	Plate 64	*Quinqueloculina sp. 33*	AS10	26.043669	50.625141	0.4
497	Plate 64	*Quinqueloculina sp. 14*	AS10	26.043669	50.625141	0.4
498	Plate 65	*Quinqueloculina sp. 20*	T3-3	26.46667	54.98333	31
499	Plate 65	*Quinqueloculina sp. 17*	T4-1	26.33333	55.5	23
500	Plate 65	*Quinqueloculina sp. 16*	T4-2	25.83333	54.96666	22
501	Plate 65	*Quinqueloculina sp. 15*	T4-1	26.33333	55.5	23

502	Plate 65	*Quinqueloculina limbata*	T4-1	26.33333	55.5	23
503	Plate 65	*Quinqueloculina sp. 32*	AS10	26.043669	50.625141	0.4
504	Plate 65	*Quinqueloculina limbata*	T15-1	29.61667	50.28445	19
505	Plate 65	*Quinqueloculina seminulum*	MP10	26.043513	50.625367	0.4
506	Plate 66	*Quinqueloculina carinatastriata*	MP14	26.044472	50.626444	1
507	Plate 66	*Quinqueloculina carinatastriata*	MP4	26.043374	50.625523	0.02
508	Plate 66	*Quinqueloculina carinatastriata*	MP4	26.043374	50.625523	0.02
509	Plate 66	*Quinqueloculina carinatastriata*	MP14	26.044472	50.626444	1
510	Plate 66	*Quinqueloculina carinatastriata*	MP12	26.043617	50.625221	0.02
511	Plate 66	*Quinqueloculina cf. Q. myagmarsuren*	T5-4	26.635	53.96666	28
512	Plate 66	*Quinqueloculina cf. Q. myagmarsuren*	T8-2	26.68472	52.75	24
513	Plate 66	*Quinqueloculina eburnea*	MP14	26.044472	50.626444	1
514	Plate 67	*Quinqueloculina akneriana*	T1-1	NA	NA	20
515	Plate 67	*Quinqueloculina bosciana*	Ta-1	26.54	56	NA
516	Plate 67	*Quinqueloculina sp.*	AS10	26.043669	50.625141	0.4
517	Plate 67	*Quinqueloculina sp.*	AS10	26.043669	50.625141	0.4
518	Plate 67	*Quinqueloculina sp.*	AS10	26.043669	50.625141	0.4
519	Plate 67	*Quinqueloculina sp.*	MP10	26.043513	50.625367	0.4
520	Plate 67	*Quinqueloculina sp.*	AS10	26.043669	50.625141	0.4
521	Plate 67	*Quinqueloculina sp.*	AS10	26.043669	50.625141	0.4
530	Plate 68	*Quinqueloculina erinacea*	T16-4	29.70111	49.90139	21
531	Plate 68	*Quinqueloculina erinacea*	T5-2	25.97499	54.48333	24
532	Plate 68	*Quinqueloculina cf. Q. subcuneata*	T8-2	26.68472	52.75	24
533	Plate 68	*Quinqueloculina cf. Q. subcuneata*	T4-3	26.43333	54.48333	18
534	Plate 68	*Quinqueloculina cf. Q. subcuneata*	T4-3	26.43333	54.48333	18
535	Plate 68	*Quinqueloculina cf. Q. subcuneata*	Ta-1	26.54	56	NA
536	Plate 68	*Quinqueloculina sp.*	T2-1	26.56749	55.98244	21.2
537	Plate 68	*Quinqueloculina granulocosta*	T2-1	26.56749	55.98244	21.2
538	Plate 68	*Quinqueloculina bidentata*	AS10	26.043669	50.625141	0.4
539	Plate 69	*Quinqueloculina cf. Q. quinquecarinata*	T6-4	25.55248	53.98485	21
540	Plate 69	*Quinqueloculina cf. Q. quinquecarinata*	T7-2	26.38334	53.46667	21
541	Plate 69	*Quinqueloculina cf. Q. quinquecarinata*	T4-3	26.43333	54.48333	18
542	Plate 69	*Quinqueloculina sp. 13*	T11-2	27.66666	51.13473	20
543	Plate 69	*Quinqueloculina sp. 14*	T16-4	29.70111	49.90139	21
544	Plate 69	*Quinqueloculina sp. 26*	T14-1	29.16667	50.53333	22
545	Plate 69	*Quinqueloculina sp. 27*	T14-1	29.16667	50.53333	22
546	Plate 69	*Quinqueloculina sp. 04*	MP6	26.043403	50.625499	0.04
547	Plate 70	*Quinqueloculina sp. 02*	T4-3	26.43333	54.48333	18
548	Plate 70	*Quinqueloculina sp. 07*	T5-1	26.13333	54.48333	24
549	Plate 70	*Quinqueloculina sp. 06*	T4-3	26.43333	54.48333	18

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PAPER OUTCOMES OF THIS THESIS

1. Amao, A.O, Kaminski, M.A. & Setoyama, E. (2016). Diversity of Foraminifera in a shallow restricted lagoon in Bahrain. *Micropalaeontology*. 62(3) 00-00
2. Amao, A.O & Kaminski, M.A. (2016). *Pseudonubeculina arabica* n.gen. n.sp. a new Holocene benthic foraminifera from the Arabian Gulf . *Micropalaeontology*. 62(1) :81-86
3. Amao, A. O., Kaminski, M. A., & Frontalini, F. (2016). Morphological abnormalities in benthic foraminifera caused by an attached epibiont foraminifer. *Journal of Micropalaeontology*, jmpaleo2015-032.
4. Amao, A. O., Kaminski, M. A., Frontalini, F., Rostami M.A, Gharaie M.H.M, Lak, R. (submitted) Distribution of benthic foraminifera along the Iranian Coast. *Marine Biodiversity*
5. Amao, A.O & Kaminski, M.A. (submitted). *Pseudotriloculina hottingeri* sp. nov: A new benthic foraminiferal species from the Eastern Arabian Gulf . *Journal of Foraminifera Research*
6. Amao, A.O., Babalola, H & Kaminski, M.A. (submitted). Natural background deformities, diversity and distribution of foraminifera from hypersaline Gulf of Salwa. Intended for *Journal of Foraminifera Research*
7. Amao, A.O., Qurban, M.A., Kaminski, M.A. & Frontalini, F. (in progress). Distribution of benthic foraminifera offshore Arabian Gulf. Intended for *Systematics and Biodiversity*

8. Amao, A.O., Qurban, M.A., Kaminski, M.A. & Joydas, T.V. (in progress). Status of Foraminifera living (Rose Bengal stained) Community offshore Saudi Arabia Based on a Once-Off Sampling. Intended for *Marine Pollution Bulletin*

BOOK IN PROGRESS

1. Amao, A.O & Kaminski, M.A. (in progress). *Atlas of benthic foraminifera of the Arabian Gulf* .